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Bent Timber Ships and Universal Wood Bending

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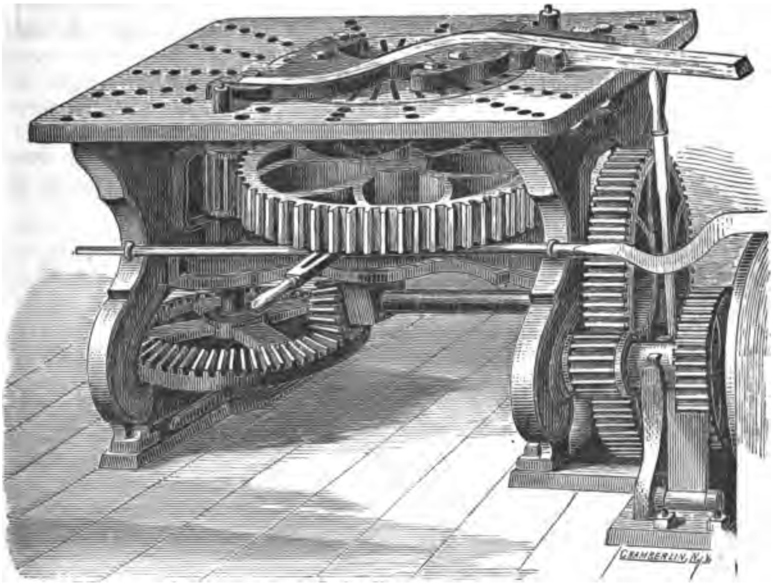
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BENT TIMBER SHIPS

AND

UNIVERSAL WOOD-BENDING MACHINERY.

THE STRUCTURE AND GROWTH OF TREES.

On examining a section of the stem of an oak or other timber tree, we observe the following parts: First, the pith or its remains in the centre; secondly, the bark on the outside; thirdly, a mass of wood between the two, made up of concentric layers known as the annual rings, which are intersected by a series of ray-like lines or silver grains, passing in direction from the centre to the circumference.

The medullary sheath is a layer of vascular tissue, immediately surrounding the pith. Its integrity is highly necessary to the life of the young tree.

The medullary rays are of a fibrous growth, at right angles to the pith, and are like a series of cross partitions formed at intervals from the root to the apex of the tree. These rays or grains afford the media of communication between the pith and the bark. Their growth is outward from the first layer of wood, and they constitute the woof of the tree, as the grains running from the top to the root may be said to form the warp. This interweaving of horizontal with vertical growths of fibres gives strength and beauty to the wood. In proportion as the medullary rays are strong and irregular in growth, the wood is difficult to work, and particularly to split. These rays may be considered as a series of *fastenings*, by which the outer and the inner annual rings are more firmly united across the vascular system. As the tree enlarges new rays are formed at intervals between the primaries, and grow outward in slightly divergent course, through the inner to the outer bark, from limb to root. In the oak they are very distinct, and to the fibres growing in large assemblages the floral appearance and peculiar beauty of this wood is due.

The bark forms the covering of the tree. It may be considered as composed of two structures united in one, viz: the outer part which is cellular, and the inner which is vascular or woody, and which forms a link in nature of substance between the wood and its covering. The inner part of the bark consists of several layers of small interlaced bundles of woody fibres, connected by loose cellular tissue. On its inner surface it is smooth, being opposed to the smooth wood, and is covered by a semi-fluid, called *cambium* or formative fluid. Its meshwork formation permits the medullary rays to pass through it and maintain a connection with the cellular or outer part of the bark and an electrical communication with the atmosphere. The more apparent use of the bark is to give protection to the wood, but if the bark did not clothe the tree there would be no *cambium*, and without this fluid there could not be a deposition of fibre; and thus it is that the presence of bark is essential to the growth of a tree. The bark contains a large number of air vessels, and not only conveys refuse matter from the leaves to the soil, but is also a depositary of elaborated secretions. This is seen in the oak bark yielding tannin, the cinchona bark producing quinine, and the fir tree emitting turpentine.

The wood is the most important formation of the tree. We find it constituting nearly the whole body of the trunk, and its structure arranged in a very systematic manner. The cross section of a stem shows a series of circles around the heart, increasing in diameter, and separated by wider intervals as the bark is approached. Thus the trunk is composed of numerous zones inclosed within each other. Between these zones, or annular layers of fibre, are situated the capillary tubes or vessels forming the circulating system of the tree. Next we observe the medullary rays passing in straight radiating lines across the zones from the pith to the bark. Splitting always takes place more freely in the lines of the rays and capillary circles; but the radiating fibres of the rays, passing through a stick of timber in almost every dirccion, nevertheless bind the zones very closely and firmly together.

Wood is formed by the instrumentality of the green leaves during the growing season, which is the one of most light and heat, and passes down in a fluid condition toward the root, between the inner bark and the wood growth of the previous year, perfectly enclosing the latter. To the leaves there is brought by the action of the roots and through the capillaries of the trunk a supply of *sap*, which is constantly evaporating into the air. This sap consists of water, with some carbonic acid, saline matters and a little ammonia. From the air surrounding the leaves abundant stores of carbonic acid are drawn into their pores to become food for vegetation. The sun's light, acting on the carbonic acid in the presence of the green matter of the leaf, decomposes it—an effect not otherwise attainable—and by this means brings into existence those compounds of carbon and water which are known as sugar, starch, gum, and which are products depended on to sustain not only vegetable, but animal life. The visible tree and the invisible atmosphere are composed almost entirely of the same substances. Elementarily, they are almost identical. From one to five per cent. of the tree, its organic or mineral portion, its ash, comes from the soil; the remainder, the main bulk of the wood, 95 to 99 pounds in a hundred of its weight, has the same constituents as the air. For proof of this we consume the wood, when all but its ash dissolves into gases, and, rising upwards, is converted into air. The coloring of the wood is influenced by the constitution and action of the bark in depositing coloring matter in the cellular tissue at the time of formation.

The roots of trees are composed of nearly the same tissues with the stem, viz., woody fibre, ducts and cellular tissue. The chief functions of the roots are, to sustain the tree, and to absorb from the soil and supply to its stem all the fluids and substances in solution which enter its circulating systems. Effete and deleterious substances are also emitted by the roots. Although the sap ascends the capillaries of the trunk from the roots, it flows still more copiously between the wood and the bark. If the bark be stripped from a tree, the circulation ot the sap is greatly diminished thereby, soon ceases, and the tree will gradually perish. The growth of the tree depends in large measure upon the health and vigor of the roots. At the butt, the largest grains and the greatest growth is found on that side of the tree which has the largest root or roots, and the heart lies nearest that side of the tree which has a deficiency of root extension and vigor.

The leaf is the structural type of the entire tree, representing, as it does, in its composition every organization, growth and particle which is found in the stem, and none other. Thus, there is cellular and vascular tissue inclosed on each side by a cuticle. The surface is commonly marked by a number of ridges, which are called veins, and which consist of woody tissue, spiral vessels and cellular tissue, and they are retained in their position and the intervening spaces filled up by cellular tissue. The tissues of the veins are brought in close proximity in the *petiole* (which is a small stem supporting the blades of the leaf), and having passed through it into the stem of the tree, one part enters the bark, whilst the other traverses the wood and penetrates to the medullary sheath, at the centre of the trunk. Thus, every leaf is in direct communication with the stem, and not only so, but each leaf is a prolongation of the very spinal vessels and wood of the stem. The similarity between the leaf and the stem of the tree may be carried yet further, for not only do the same structures enter into the composition of both, but in both there is a double set of vessels, one of which conveys the fluid from the root to the leaf, and the other carries it back again from the leaf to the root. The leaf is the laboratory of life. Its power resides in the green matter, termed *chlorophyll*, which serves the important purpose, under the action of the sun's light and heat, of decomposing air and water, throwing off oxygen gas and commencing organic operations. The decomposition of carbonic acid is the starting point of life and growth. The oxygen thrown off produces a gaseous current outwards, which is compensated by the substitution of a stream of fresh carbonic acid from the air; thus the aliment of the tree is recruited. This action of the leaf will not take place in the night or in darkness, nor will it occur when the leaf acquires the orange and red tint of Autumn. When the leaf is *green* in color is its time of vigor; then it absorbs the red and allows the yellow and some blue rays of the solar light to pass through; but the green color having faded or changed with the season, or from any cause, these active rays are more or less cut off, and the functions of the leaf are altered or cease althogether. The first effort of growth in the green leaf is the formation of soluble starch or dextrine, characterized as the most important body in organic chemistry. The thickening of the sap by the dextrine serves to solicit fresh supplies of fluid from the soil; other changes and alterations in the plant food occurs, and under the influence of these causes the circulation extends, and the tree expands and grows. The chemical action of the dextrine itself is remarkable. It possesses the power of changing into starch, sugar, gum, cellulose and woody fibre, all these being primary compounds of carbon with water, nearly in the same proportions. The oils and acids, and other secondary bodies found in trees are derived from these compounds by combinations and processes peculiar to the nature of each particular kind.

The living tree holds communication with the earth and water beneath, and the air and sun above it, by means of roots, bark and leaves without, and the system of circulation within its trunk. Its healthy growth depends upon the presence and normal action of all its members. Its fluids and deposits will be imperfect if wanting in any essential ingredient, or deprived in any degree of necessary light, heat and electricity. A healthy growing tree undoubtedly produces the strongest and most durable wood of its kind, because its fibre and grain has been formed under natural influences. If a tree be denied water and the necessary mineral food to its roots, or be stripped of its leaves, or peeled of its bark, it will gradually and surely perish, as by starvation. If all these things be done to it simultaneously, it will immediately cease to live *as a plant*, and become timber. When a tree is felled, the root circulation is cut off; fluids will no more ascend the stem, as the force of ascension resides in the roots, but the bark and leaves will continue their functions until their powers are exhausted. The juices will flow into the stem for a while from the leaves of the top and branches, but this circulation soon becomes sickly and poisonous to the tree, and causes untimely decay. If, however, when a tree is felled, it is also cut off from the top, not only the upward, but the downward or vascular circulation very soon ceases. The only circulation left is that between the pith and the bark, but this will not cease until after the bark has exhausted its powers upon the fluids within its reach and sown the seeds of premature dissolution throughout the wood of the tree. The *plant life* of a tree should be completely destroyed at the time of felling it for timber, or changes injurious to the lasting qualities of the wood will take place. Imperfect formations are the most unstable and the first to decay. The felled tree should be immediately converted into timber, with every fibre and tissue of bark removed from it.

THE CONSTITUTION OF WOOD.

The matter of woody fibre consists of two constituents, *lignine* and *cellulose.* These bodies have the same proportion of carbon, but differ slightly in their combining numbers of atoms, of hydrogen and oxygen. Lignine is not identical in composition with any other substance, while cellulose is composed of the very same elements, in like proportions, though differently grouped, as starch, dextrine, and tragacanthine—substances of a glutinous or gummy nature.

The structure of the fibre is invisible to the naked eye. With the aid of the microscope it is found composed of spindle-shaped *cellules* or minute elongated cells, the one growing from the other in continuous line, and joined together laterally on all sides, with companion lines of cellules arranged in such order for strength that the extremities of the cells overlap and break butts, so to speak, in the most mechanical manner. The walls of the cellules are of *cellulose,* a substance endowed with skin-like toughness, while the interior, insoluble and fixed matter of the fibre, is *lignine.* As the bark envelopes and adheres to the wood of a tree, so does a membrane of cellulose contain and cohere to each separate atom of lignine, of which there are many in a fibre. And as the cellules with their contents build up the fibres, so do the fibres in turn, by aggregations, construct with their vascular tissues the woody layers of the tree. The annual layers of fibrous growth are like so many skins that may be split circularly from root to branch into an indefinite number of veneers, in some kinds of wood, as thin as paper, and yet every veneer will have several thicknesses of fibre arranged and conjoined to the utmost advantage for strength, solidity and structural coherence.

Fine linen fibre offers a beautiful illustration of the chemical properties of cellular lignine. It is white, tough, tasteless, insoluble in water and innutritious. Strong sulphuric acid converts it in the cold state into a tough mass, resembling a solution of dextrine, a name given to the mucilaginous fluid of vegetables. By warming the mixture, the lignine will be charred; by boiling, it will be converted into a solution of grape sugar, which may be purified, filtered and dried. Cotton fibre, on the other hand, presents us with a specimen of nearly pure cellulose, with little to distinguish its reactions from those of linen. Both bodies have the same general properties, they may both be made into paper in the same way, they both dissolve in cold sulphuric acid into dextrine, and they both may be made to yield guncotton.

From the simplest vegetable, consisting of a single cellule, with one side adhering to the moist wall, and the other exposed to the rays of the sun, we may learn the principle upon which vegetable and also animal bodies are constructed. The cell wall is everywhere complete. No microscope can discover any palpable apertures in it, but it nevertheless allows some elementary bodies to pass through it to the interior, or is porous. Its porosity is the same which belongs to all masses of matter, and which is due to the unseen spaces existing between the atoms. Through these unseen interstices such bodies alone pass as have a natural attraction for the bounding membrane; and such alone into the interior as have a similar relation to the fluid, solid, or gases which may occupy it.

The tallest tree and the strongest wood are alike formed and built up of infinitesimal elementary *cellules* or membranes, filled with woody matter. These cellules with their contents are grouped into fibres, the fibres are united into layers, and the layers are disposed over each other, forming *grains* or annual rings of growth. Between the grains, or layers of solid wood, a system of capillary tubes exists, through which fluids containing matters for the nourishment of the tree ascends to the leaves. These tubes contain water, carbonic acid, ammonia, phosphoric and sulphuric acids, in combination with certain bases of potash, soda, lime and magnesia, chiefly, these being in minute quantities. Upon the decay of the timber the contents of the capillary tubes first suffer change, passing into an impure solution of carbonate of ammonia. Next, the cellulose matter of the cellules is decomposed, and speedily the coherence of grain, layer and fibre is broken up. The largest capillaries exist in the sap-wood, through which the principal upward circulation is conducted. In the heart-wood the tubes are gradually compressed into very small spaces, and in some kinds of hard and very durable wood seem to disappear altogether. The wood for which water has the strongest affinity has the largest capillaries, and that kind having the weakest attraction has the most numerous canals. The latter will season more rapidly than the former. Seasoned wood immersed in water soon imbibes minute quantities throughout its fibrous system by the action of the capillary tubes, and swells in bulk. If, however, the ends of the wood, and consequently the mouths of the tubes, be kept from the water, the wet will not soak through. Were it otherwise, wood would be wholly unfitted for the thousand uses to which it is put as coverings and enclosures. Green or water-soaked wood placed wholly in the air soon becomes dry, the electrical relations of wood to water being disturbed in favor of the atmosphere, and the tubes and fibres giving up to it the surplus moisture in the form of vapor, and the wood shrinking to its minimum dimensions. Heat and cold both affect the action of the capillaries, and induce changes in their absorbing powers.

The force which binds together the cellules and fibres of wood is attraction, and is called *cohesion*. Its intensity varies in different kinds of timber. The fineness of the cellules and the closeness with which the fibres are laid determines the cohesive strength. Newton concluded that cohesion did not act at a distance exceeding the millionth of an inch. The force of attraction whereby fluids are absorbed or drawn into the capillaries of wood is less than the whole, but probably exceeds half the cohesive force; while the chemical force by which elements are compounded and disunited is, of course, greater than that of cohesion. Above all these forces the living principle asserts its superiority during the lifetime of the tree and the formation of wood. The force which the living root exerts upon the flow of sap upward, in defiance of gravity, is wonderful. Even when the connection of a birch root with its tree had been severed, it maintained a flow of sap equal to 75 feet of water pressure to a square inch by a mercurial guage.

In the gaseous state, matter is chiefly distinguished for *elasticity;* it has no cohesion, and but little chemical activity. Cohesion is first acquired in the fluid state, in slight degree; and in this state chemical power develops in most active form. In the solid state cohesion would secure permanence to matter, were it not that chemical affinity overcomes it with force, by the assistance of fluidity, heat, light, and electricity. Drying up a mixture retards chemical union, and in some cases stops it by restraining the electrical excitation within the limits of cohesive action. Similarly, seasoning wood increases at the same time both its strength and durability.

The causes which act to destroy wood are related to the necessary consequence of organization. By deoxydation of carbonic acid, the sun's rays created the elements of woody growth in the green leaf; by oxydation and the consequent formation of carbonic acid and water, the woody fibre will cease to exist in organic form, but as gases and ash will pass away to the air and the earth it originally came from. In every form of decay, the most active agent is oxygen gas. Without this agency, the presence of free moisture in the timber, and heat above 40° Fahr. in the surrounding medium, the first action, which is fermentation, could not take place. After fermentation comes a slow combustion, the continued absorption of oxygen, and the constant formation of carbonic acid and water. By this change the cohesiveness of the cellulose of the fibres gives way, the fibres lose their tenacity, continuity, and cohesion, the woody mass is metamorphosed, and a brown, friable body, called *humus* is produced. Sometimes only the outside of the wood is attacked by the oxygen; then it moulders and crumbles away, leaving the fibres not immediately exposed to the air intact. In such cases the disintegrating action can be stopped by protecting the exposed surface from the bite of the destroying gas.

Wood submerged in water of common temperature will endure for an incredible period of time. The water dissolves and washes from the capillaries of the wood all unassimilated supplies of matter provided originally for the growth of the tree, and which, since its conversion into timber, has become dead and foreign to its new state. The matters which might have served as food to the living tree, act as poison to the manufactured timber if they remain in it free to enter into destructive combinations with outside elements. Timber from the raft, in clear running water, if exposed to the air seasons quickly and endures well. Water seasoning not only removes substances liable to *ferment*, but the immersion protects the wood from the action of heat. In the same way the proper application of *steam* cleanses the timber and hastens the drying up of the surplus moisture within the wood; and it has the additional advantage over water that the heat effects changes upon the extraneous matters which render them much less liable to chemical affinities involving decay. Seasoning wholly in the air preserves wood by drying up the fluids and solutions present in the wood; and if this be done in time, fermentation is prevented, even under the action of heat. So that, whether we deprive wood of its surplus moisture, or cleanse it of its deleterious matters in solution, or fortify its free substances against chemical action, we may season and preserve it for a long time, provided it is not to be exposed to very unwholesome influences. The natural protector of wood is pure, dry air. Water is friendly when it is pure, or wholly submerging the wood; but under the continued action of heat, evaporation affords the only security against rapid changes of constitution. It is to maintain dryness, that ventilation is as necessary to the preservation of timber as light is to the growing tree.

To thoroughly season white oak timber, which is reluctant to part with its interior moisture, there is no course so speedy and beneficial as proper steaming under a low pressure and in a moderate current of steam.

THE PHILOSOPHY OF WOOD-BENDING.

In harmony with its formation and the circumstances of its growth, wood is constituted with a remarkable property for bending and flying back to form when released from constraint. The former characteristic is known as flexibility, and the latter as *elasticity*. These qualities are significant of the tree life. With its roots firmly fixed in the earth, its trunk towering aloft, and its top and branches tossed to and fro by the waves of the atmosphere, bending and springing must be perfectly *natural*. By one law of its being, the tree must keep its place where rooted, and by another law it must move to the tremor of the slightest breeze. In bending and springing back its exercise is constant: day and night, summer and winter, there is no rest in its vegetable experience. Without flexibility in the *fibre*, the growth of trees would be impossible. The oscillating movements of the stems and branches, so necessary to their healthy functions, could not be performed in safety, and with security to the life of the rootlets, twigs and leaves, if nature had not provided for the property of elasticity in every *cellule* and fibre of the entire tree.

While bending and straightening without injury is perfectly natural to the growing tree, it has not been explained why or how this wonderful action takes place; and by what means timber may be bent by art, to a degree that nature has had no need of attempting, although she has provided for the phenomenon, and when bent may be *set* without impairing the elasticity of the fibre in the slightest measure. We have shown in our consideration of the "constitution of wood" that the fibres are composed of spindle-shaped cellules, or *minute elongated cells*, the one growing in continuous line, and joined on all sides with companion lines of cellules, each cellule overlapping another, and all united into threads or fibres by cohesion. Having clearly comprehended the structure of the fibre, as made up of spindle-shaped cells, we are prepared to notice that a tensile force, if applied in extreme degree, would be calculated to rupture their connections and separate the fibre; while, on the other hand, a compressive force would act in the opposite way to crowd the cellules together, thereby increase their cohesion and store up a resistance, which, when the strain was relieved, would be exerted as *elasticity* to restore them to normal positions. As self-preservation is the first law of nature throughout her domain, we may see plainly why all vegetable fibres *prefer* to yield to a compressive rather than a tensile force, when the choice is given; or, in other words, why the tensile resistance is always greater than the compressive. The most unsafe movement is naturally most stoutly resisted—the easier movement is one of least danger to the vegetable stem, and is therefore elected.

"'Tis education forms the common mind,
As the twig is *bent*, the tree's inclined."

The wood of a tree has been educated to bend, and to bend by compression. It will refuse absolutely to bend by extension of one side, although some authors have misled their readers on this point, teaching that in bending a wooden beam, one side is extended and the other compressed. We, whose business it is to bend timber, know better, and that good philosophy always agrees with experience. On the average of the various sorts of wood, the compressive resistence is only *sixty* per cent. of the tensile strength. In white oak, the compressive resistence is only about *one-half* that of the tensile strength, which is one reason why this timber is an excellent wood to bend. Wood will not *stretch* without rupturing the fibres. When it has bent to such a degree, that the side subject to compression will yield no more, then the outer fibres of the side under tensile stress must break, if the bending force is continued. The side under tensile strain will not extend, to accommodate the operator. But the side which has been shortened in bending will stretch out to its former dimensions, when released from constraint and assisted to recover from the *set* which may have been given. This is the law of wood bending. Were it otherwise, wood could not be produced. Trees could not grow, but would be destroyed by the ever-changing currents of the atmosphere, if they were subject on any side to extension of fibre. In the first place, the bark would be cracked crosswise, and the air admitted to dry up the cambium; next, the circulation from the roots and the leaves would be intercepted and obstructed; finally, all the processes being interfered with, the tree would become diseased, and fall a prey to doom. It is, therefore, a law of the vegetable kingdom that plant life cannot be continued, if begun, under condition of stretching one side in the act of bending to the breeze; but, on the contrary, all the bending of plants must be by contraction of the side opposite that to which the force is applied, and that in the form and disposition of the cellules of the fibres, and their endowment with elasticity, provision has been made to restore to place and position favorable to growth, every fibre and organ of the living tree, when the force which bent them aside has been removed. Thus flexibility and elasticity protect the growth of wood.

Not only in bending and springing to place are these qualities useful in timber, they are equally available in receiving impulse and resisting concussion; in opposing momentum and transferring vibrations, without prejudice to the integrity of the body. The street wear of wooden pavements will illustrate what a wonderful repetition of thumps even soft pine will endure on the ends of the grains. Even the iron-built ship of war must have her armored side fortified by a *backing* of wood to prevent the hull being broken through in battle, and the bottom should be defended in like manner from the violence of rock and shoal. *Vibration* alone cannot break and destroy wood, while it is terribly destructive of common iron.

Whilst wood bends naturally by compression, iron bends by extension mainly. This is owing to the law of its production, and the nature of its formation. But for its *ductility* wrought iron could not be made.

The harder it is, the better it will bear compression; the softer it is, the better it will extend under the hammer or the rolls, in a cold or heated state. Iron cannot be worked without extension; in this it is the opposite of wood. Flexibility and elasticity, as they exist in wood, are unknown in iron. In their place, iron possesses ductility. Iron bends by extension of one side; wood bends by compression of one side. Opposite bendings will separate a bar of iron; wood cannot thus be separated unless the sides be fractured at each inflection. By opposite bendings, iron is lengthened; by the same process wood may be shortened. The cause of these differences between iron and wood may be found in the ratio of the tensile to the compressive strength. In iron the compressive resistance is the strongest, while in wood it is the weakest. While in this respect iron is the opposite of wood, the tensile strength being in cast-iron only one-seventh, and in common wrought-iron only one-half that of the compressive resistance, it is not unfrequently the case that no distinction is made by amateur mechanics between the bending and springing qualities of the two materials.

On bending a thick piece of wood, in the cold state, we find it will flex, without danger of breaking, until its compressive resistance on the contracting side has been so far augmented as to become equal to the tensile strength of the side to which the force is applied, when a further addition of stiffness, by an increase of curvature, would make the contracted side the stronger, and rupture of the outer fibres of the side, now liable to extension, would occur. Up to this point, however, we should have accomplished a certain degree of curvature, depending on various circumstances, not necessary for our present purpose to investigate. If, again, we prepare a piece of wood for bending, which is generally done by steaming or boiling, although there are other processes of softening, we shall find our power of flexure materially increased. The steaming takes nothing from the tensile strength of the wood, while its compressive resistance may be lessened several hundred per cent., and, consequently, the piece may be bent to a curve of very much shorter radius than in the unprepared state, before the convex side will show any signs of fracture. But there is a limit to the operation of bending by the aid of a softening process alone. Gradually the closeness to which the cellules of the fibres are forced, in the side under compression, induces stiffness, and accumulates resistance to our power. When this resistance to compression shall have become equal to the tensile strength of the side which has acted to make the bend, then rupture will take place if we carry the inflection farther. From the consideration of these two cases we learn that wood-bending, as a process and a result, is a trial of *tensile against compressive strength;* and that the philosophy of inflecting timber with certainty and success must be to prevent the fibres of the tense or convex side from stretching apart or breaking, while the cellules of the fibres of the condensed side are pressed closely and firmly together. By the use of a metal strap this may be accomplished,—the tense side of the timber may be so reinforced as to take all the stress of tensile application, and secure the compression of the wood from side to side, when it will be possible, by proper machinery, to bend a stick much further than without a strap, and to the full extent of its compressive endurance, without fracturing its convex side. Of course, in this ultimate process of bending, the wood must be prepared by steaming or otherwise, to enable its fibre cellules to make the necessary movements with facility.

And now we may inquire about the preparation of timber for bending. If to be bent in the cold state without preparation, to a moderate curve, green timber bends the best. This is because of wood being softer in the green than in the dry state. Seasoned timber is stronger, or has more compressive resistance, than that which is freshly cut. Its superior stiffness is due to the dryness and *set* of its fibres. But the presence of sap or surplus water in timber, although it causes softness and facilitates moderate bending, is a hindrance to the operation, if we wish to extend it to a sharp angle. In other words, the minute spaces into which the cellules of the fibre must be crowded, as well as the capillary tubes into which the grains must be expanded in contracting their length, must be free from sap, water, gum, or other extraneous substances, if we would have sharp and perfect bends. Seasoned timber takes steam better than green, for the reason that its pores, so to speak, are open to its admission. Green timber not only takes more time than dry to steam properly, but requires a longer time to dry and *set* when bent. The operation of bending with a metal strap will squeeze the water out of a stick where considerable compression takes place, showing that from timber to be bent we should first extract the moisture,

Timber, to be properly disposed for bending, should have the heart-wood put next the holding strap, and the sap-wood next the bending form. The reason for this is, that the heart-wood is denser than the sap-wood, and less flexible, the growth of the tree having compressed the cellules of its fibres and the capillary tubes into closer relations, and depositions of various substances having been made in every channel of circulation. The sap-wood has the largest capillaries and the softest fibres, and, with the sap removed, its structure is wonderfully adapted to flexile and elastic movements. The worker in wood has always observed that the timber and lumber of all trees spring *from* the heart, and for this reason, nature has invested the outside wood of the tree with the greater contractile power, the better to resist and recover from the bendings of the rude atmosphere in which it lives.

We have been explaining the principles on which *thick* pieces of wood may be successfully bent, and it will next be in order to show how the wood is *set* in the operation. The set is given to the bend, first, by the severe *compression* that the wood undergoes; second, by the *time* its elastic action is forcibly repressed; third, by the extraction of *caloric*—the heat of the stick being reduced by cooling from 240° to the prevailing temperature of the surrounding air; fourth, by *drying* up the moisture in the wood, which may be hastened in a drying-room, or by a special application of heat. It is a principle in bending that the thicker the piece which is bent the quicker it will set. The principal reason of this is, that the thicker the piece the greater must be the compression, the outside length being the same, and there being no possibility of stretching it. Hence we see that compression first gives the set; the other influences assist in retaining it. Severe compression causes an overlapping movement of the cellules of the fibres, and a solidification of the walls of cellulose and the particles of lignine which compose the fibres, and the drying process supervening, the wood is farther stiffened against an elastic movement. In bending ship knees to a right angle with a short radius, it has been found expedient to shorten the sticks from a sixteenth to a twelfth of an inch to the foot of length, by hydraulic pressure, before bending them. Of course, this is done when they are hot from the steam stove.

The use of the archer's bow, and the bending of *thin* pieces of wood has led some persons to think that there must be great difficulty in giving and keeping the set in bent timber of considerable dimensions. They have imagined that wood must be elastic in proportion to its thickness, which is a mistake so far as springing back is concerned. The Indians of Puget Sound use arrow-bows of yew, thorn-apple, or red cedar wood, with sinews or rawhide glued fast on the outside and made a part of the bow, to increase the elasticity and tensive power of the weapon when the arrow is let fly. But it will be observed that the extraordinary springing quality of the bow thus prepared is due in great measure to the *stretching* of the sinews or rawhide on the tense side of the bow. When the arrow is let go they instantly contract with great force, and their elasticity is added to that of the wood in the bow to project the missile. The sinew on the outside of the bow prevents set in the wood while it is momentarily drawn. But the metal strap on the outside of a stick of timber is intended to serve the opposite purpose—to give the set—as it does not stretch itself, and will not permit the outer side of the wood to extend, but compels compression in every cellule and fibre of the piece. A very thin piece of wood, if bent like a bow and immediately released, instantly regains its straightness. But there is a thickness at which every kind of wood if bent and instantly released will have acquired a set, and will not fully regain its straightness. The comparative elasticity of various woods may thus be determined.

A knowledge of these principles has led to the invention of machinery for bending timber for shipbuilding. From time immemorial shipbuilders have bent their planks by a due application of heat and moisture, but it is not in history, until the present century, that any of them discovered how to bend *frame timbers* and *knees*. If a plank was too thick to bend without fracturing the outside fibres, the difficulty was surmounted by a cut of a whipsaw, dividing the plank into two or more thicknesses in the place where the greatest bend would come, the inner thickness being free to *slip* an end as the bending operation was performed. The use of spawl-boards nailed on the outside of planks to be greatly bent or twisted was the nearest approach to the employment of a strap of iron or steel as we see it utilized in machine bending. But the spawl-board and the steel strap serve totally different purposes. The former confined the splinters arising from the stretch of the fibres, and caused them to set closely in their places, while the latter reinforces the outside of the timber, and preventing a tension of the wood, causes the inflection to be made from outside to inside of the stick wholly by compression, and without starting the grain.

After timber has been properly bent and thoroughly set, its elasticity becomes reconciled to the new form, and apparently with undiminished power. While, in order to acquire a perfect balancing of forces throughout the piece, it may spring a little on being released, a stick of machine-bent timber, or a knee, will resist as stoutly as ever any force tending to give it another than the bent form to which it has set, unless it be steamed again. Nor can the wood, where very much solidified in bending, be soaked in cold water sufficiently to straighten it in a very marked degree without the application of power. A piece of oak bent to a right angle, and shortly afterwards re-steamed and partially straightened by a moderate force, refused to become quite straight under a tensile strain in a testing machine, which broke it at 14,480 pounds to the square inch. In a bent timber where the compression has been greatest, there is the least disposition to reaction. The ends of a piece are the most inclined to creep back, and the action is chiefly confined to the thinner end of the two. A very slight security suffices to keep this waywardness under control until TIME accomplishes its complete subjection. The difficulties in working bent timber are novel but trifling, and are as easily overcome by practice as in working unbent wood, which is subject to its own peculiarities in springing, as every mechanic knows.

WOOD-BENDING MACHINERY.

Wood-bending machines are of various types, but all involve the same principles. For carriage and furniture work, and the making of agricultural implements they are now in use in nearly all the leading manufactories in the United States, and some of the countries in Europe. In shipbuilding, where they would subserve the highest usefulness, comparatively little has been done towards their introduction. In fact, they have never been put upon the market. The invention was perfected in the darkest days of commercial depression, and when the *mania* for iron vessels first excited the country. The company holding the patents, having spent much time and money and accomplished the building of a successful machine, felt that they had performed their duty to the shipowning fraternity—that the introduction of their machine would be the work of time, and might wisely be postponed to the dawning of a brighter day. In the best of times, improving changes in the construction of vessels must necessarily be of slow growth. There are many interests to be harmonized before any new principle can be generally adopted. Anything of importance that is deemed an experiment will be sure to meet with disapproval from some quarter. Before bent timber ships can be built in any numbers, there are shipbuilders, shipowners, shipmasters, marine inspectors and underwriters—four or five distinct classes of persons to be informed of the utility, and convinced of the necessity of the proposed improvement. Each of these classes has to examine it in the light of their own interest and advantage. Shipbuilders will hesitate to employ machinery that they can do without and continue to make money, especially if it is expensive, and, moreover, if the owners for whom they build do not insist upon its use. Ship owners always have in view the classification of their vessels; any improvements not set down in the *rules* of the societies which characterize shipping are to them of dubious import. Then they have their builder and master to advise with, and these are not likely to counsel the adoption of what they have had no experience with themselves, though they may believe it to be a decided improvement upon the old way of building. Last comes the marine inspector with his rules, embodying all the wisdom of all the sages in ship-building since the launch of Noah's Ark. Whatever may be his intelligence and private opinion, anything new and untried by the past generation is all wrong with him as an official. What the dead never knew, the living cannot learn—such is the inspiration of most systems of inspection. As a result, the present is consumed in overcoming the past, progress in ship-building is very much retarded, and good men are discouraged from efforts to introduce improvements. If you convince the inspector on the point of strength, he may yet doubt on the score of *durability*. If, happily, doubts are converted into certainties upon all points, you have yet to convince the "BOARD" or the "ADMINISTRATION." It is, therefore, a work of time to introduce so great an improvement as *the bending of long timbers for the frames of vessels*, and effect the sale of machines. Even the timber-cutters have a word to say, and some of them object that the forests are full of very crooked, cross-grained, knotty timber that it will be impossible to bend!

But the world does move, for all the seeming inaction of indifferent minds. The lover of progress should always be grateful for the acknowledgments of merit by which the disinterested are ever ready to aid the worthy inventor. In this Centennial year, the new system for lake vessel inspection, issued by Capt. E. P. Dorr, of Buffalo, proprietor of the Lake Register of Shipping, contains rules for the construction of bent timber ships. These rules represent the art and science of a council of ship-builders, most of whom were ship owners, and the marine inspectors of the lakes. This system of construction and characterization adopted by the council, upon the report of the judges, has been awarded a *medal* for merit, by the Commissioners of the Centennial International Exhibition. In the preface Capt. Dorr makes the following remarks:

"We also invite attention to the rules providing for the building of vessels with frames of *long timbers* bent to shape by proper machinery; the futtocks springing from keel to rail in single sticks, and the floors in whole length across the bottom. The framing of vessels by this method is undoubtedly the most important contrivance introduced in modern shipbuilding. Where vessels are so liable to take the bottom and go ashore as they are in the navigation of the lakes, this sterling invention ought to be generally utilized. The cost of the best plant for working on the best system in shipbuilding is not so great as to discourage enterprising builders from its use, while ship owners and underwriters will ever be found ready to pay for security from loss.

We may add that the white and burr oak timber of the Lake region is signally adapted to the *machine bending* of frames and knees for ships."

The first machine for bending timber for ships' frames, in whole length from keel to rail, was built of extraordinary strength and power, and cost a large sum of money. The building of so large a machine at so great cost, at first gave an unfavorable impression of the economy of the invention, especially at a time when the shipbuilding interest was so seriously crippled as it was in 1868–'69–'70. Following is a description of the East Boston machine on which the ship "New Era" was built, as given by a Board of four Naval officers appointed "to examine the process of bending ship timber, and whether it is desirable to introduce the system into the Navy yards":

"The machinery for bending timber has been brought by a number of years' practice to a high state of utility. It consists of a jointed mould made up of cast-iron sections which have two horizontal projecting arms on the flush side, the one above the other, forming a groove between them for the timbers. The end of each of these sections is circular, and is secured like hinges, interlocking in its adjoining section, and held together by a vertical wrought-iron pin. The sections thus united form a series of joints adjustable to any form, and may be extended to any length. This mould rests upon a circular table with a circular frame beneath, 22 feet in diameter. This table, being 3½ inches thick and pierced with slotted holes systematically arranged to receive the fastening of the mould, &c., is mounted upon a hollow shaft of cast-iron, 30 inches in diameter, and has a screw-thread cut in its outer surface at the lower end, by means of which the table may be raised or lowered and made to bear a part or the whole of its weight on the shaft-bearing. On the lower edge of the table are circular cogs into which a pinion-wheel meshes, and the power applied to the pinion revolves the table. The table has an attachment fastened on the top at its edge, called the head-block, which receives the small end of timbers and plate-strap covering the outside of timbers. The larger end of timbers is confined in a massive cast-iron clamp, which also receives one end of plate-iron strap. This clamp is mounted upon casters, and having a vertical roller on its back at the larger end, is drawn along by means of the plate-strap as the table revolves, the roller in end of clamp bearing against a vertical bulkhead raised from the floor of the building while the timber is being bent into the groove of joint-mould. The clamp, as also the head-block, have screws passing through their ends, by the use of which pressure on the two ends of the timber is communicated. This end-pressure applied to the timber draws the strap straight and to its full tensile dimensions, and when thus brought up against the outside of the timber, the process of bending commences by revolving the table. A mould for bending knees is arranged upon the same table, and is complete in all its parts, details of which it seems unnecessary to describe. The whole machinery is massive and ingenious, although easily operated."

The second machine was built for the Government, using such parts of the first as were suitable, and adding other parts, embracing all the inventor's improvements up to that time. The knee-bending machinery was erected into a seperate division. The compresser clamps, for both knee and frame bending, were fitted with hydraulic power, the better to control the end-pressure, and many other important improvements were added.

A Board of five officers of the U. S. Navy, appointed "to examine and test thoroughly and carefully" this bending machine, made the following report, April 19th, 1872:

"*Sir:* In compliance with your order of the 17th instant, we have carefully examined the timber-bending machine delivered by J. W. Griffiths, Superintendent of the Union Ship-timber Manufacturing Company, on contract, dated September 1st, 1871, and have to report that the machine is substantially built, of apparently the best material, exhibiting excellent workmanship, and it performs all the work required of it under the contract. We unhesitatingly state the machine is completed, in accordance with the terms of the contract, and that the timbers and knees which have been bent are entirely satisfactory."

The third machine was built by the same inventor for the International Exhibition at Philadelphia, where it may now be seen in operation, bending timber in Machinery Hall. This is the first machine for timber bending ever publicly exhibited.

It has a cast-iron platform erected upon legs of the same material, the upper surface furrowed with inverted T grooves, forming the bed of the machine ten feet long and four and a half feet wide. At a point in the length, the sides are swelled out to a width of six feet, to admit the insertion of a revolving table forty inches in diameter, which rises above the surface of the platform a quarter of an inch, for clearance of all projections, and the free turning of a cast-iron segment secured upon it. The table is revolved by a vertical shaft passing through a central hole 3½ inches square, the shaft being connected with gear wheels, through which the power is transmitted beneath the platform. The bending segment is secured to the table by screw bolts; it is a sort of curved platform eight or ten feet long, to which the cast-iron adjustable holders for confining the timbers are fastened by screw bolts. The holders have hinged lids and projecting arms, and the timber finds its place between them when the table and its mounted segment are revolved. The adjustability of the machine is secured by means of the segment and holders, as every machine may have as many segments and as varied patterns of holders as the work to be done by it may require. At one end of the segment, the smaller end of the timber to be bent is held by a clamp and guy-rod, which has an adjustable attachment to the table, while a steel strap secured to compressor heads covers the outside of the timber from end to end. The compressor or clamp-heads have screws so fitted as to distend the strap before the bending takes place, in order that all the tensile strain of the operation may be taken by the strap, and none of it by the timber. The larger end of the timber is placed against a roller held upright in a holder secured at the extreme end of the platform. Two or more sticks having been properly steamed may be bent at the same time. The revolving motion of the table and segment is adjusted by the necessary gearing, so as to give the operator time to drop the tops of the holders, insert iron pins through their points, and place wedges behind them, to confine the timber against the holders, which have been set to the form to which the timber is required to be bent. As the timber is wound around the form fixed by the holders, the larger end moves along against the roller until the bend is made, which may be done in two or three minutes after the timber is taken from the steam stove. The bending operation itself may be performed in less than one minute on the machine which we are now describing, a view of which may be seen in the accompanying cut.

In the process of bending, the wood is compressed or shortened in its length on the inside, and if properly done is not stretched or lengthened on the on the outside curve. Experience has demonstrated to all having practice in the using of timber that has been properly steamed and bent, that the wood is improved by the operation. By the steaming, and subsequent pressure in bending, the sap and moisture is expelled from the interior of the wood, and the fibre may be said to take its place. The result is speedy seasoning and increased durability.

The knee-bending machine is not shown in the engraving, but it is quite simple. It consists of an iron platform from which two adjustable vertical rollers project, for the purpose of holding the ends of the timber when the bending force is applied to the middle. The timber for a knee is strapped between two clamp-heads, the same as for a frame crook, and a screw in each head takes up the tension before bending, in the same way. A curved form such as the throat of the knee is required to have, is then thrust forward by screw power applied to the middle of the straight timber, which is thus bent outward until it forms the angle required for the arms of the knee, and which may just as easily be made insquare as outsquare. When bent, the knee or knees, for there may be two or more bent at one operation, may be clamped across the arms and taken out of the machine to dry and set. When necessary to have a corner opposite the throat, it may be formed by a triangular chock.

The sizes of UNIVERSAL WOOD BENDING MACHINES have been graduated as follows:

For building the largest ships and steamers—above 2,000 tons.

Nos.	Platform size in feet.	Tabe diam. in feet.	Cross section of timber in inches*	Cross section capacity.
1.	26x28.	22.	12x24.	288
2.	22x24.	18.	10x20.	200
For vessels from 900 to 500 tons.				
3.	17x20.	14.	8x16.	128
4.	13x18.	10.	7x14.	98
For vessels from 450 to 250 tons.				
5.	8x14.	5.	6x12.	72
6.	6x10.	3 ft. 4 in.	5x10.	50
For smaller vessels, yachts, &c., and bent work in other trades.				
7.	4x8.	30 inches.	4x8.	32
8.	3x6.	20 "	3x6.	18

*At the middle of the bilge.

The *knee-bending machines* follow the gradations above, and may be had suitable for boat-builders' work, or built of capacity to bend two knees, 12x12 inches, at the same time. They may be operated by the power which drives the revolving table of the long timber machine, by being geared thereto, as appendages; or they may be worked separately. The smallest sizes may be operated by hand.

Special machines for doing bent work of any kind will be constructed to order.

There are many things in the wood-worker's art not yet brought to perfection for lack of the use of bending machines. Wherever timber is wasted and strength lost by cutting *across the grain*, the bending machine should find employment. Cut No. 2 illustrates Bending Machine No. 8, for doing wheelwrights' and other work.

THE STRENGTH OF MACHINE-BENT TIMBER.

The facility with which timber may be bent by machines into the various curves required in the arts, preventing the great waste of material, which is growing more and more valuable, lends importance to the consideration of the strength of machine-bent timber. As the timber land of the country is cleared, the difficulties and cost of obtaining timber of proper size and quality for natural growth knees, floors, hooks, and futtocks becoming proportionally greater, what could be more acceptable to ship-builders than to find that machine-bent crooks are equal if not superior in strength, solidity and durability to the wood in its natural state, and may be obtained at less cost.

The inventor of the "end-pressure system of bending, Mr. Thomas Blanchard, of Massachussetts, in 1856 had so far improved his original method patented in 1852, that the invention began to be available for the use of the ship-yard. Futtocks and knees were bent, and began to be used in New York. A number of knees bent at this time was thoroughly tested by a commission appointed by the Secretary of the Navy. The commissioners were: Lieut. J. T. Worden, afterwards distinguished for his gallant command of the "Monitor" in her encounter with the "Merrimacc," and Benjamin F. Delano, Esq., Naval Constructor at the Brooklyn Navy Yard. Their experiments lasted six days, commencing July 16th, 1856, and were made at the Novelty Works in New York city. The power applied was that of the hydrostatic press. The following account of these experiments is extracted from the U. S. Nautical Magazine and Naval Journal for August, 1856.

"The knees upon which these tests were made were of the largest size, commonly used for hanging knees. In order to make the test analogous to the appliance in the vessel, a piece of oak timber of equal siding size with the knees was fastened to the body, representing a timber of the ship's frame; also another to the arm, representing the beam of a vessel. The body was secured upon an iron frame, in which the press rested; while the power was applied to the arm, on some, to contract the angle of the knee, by drawing inward to a point of rupture, and others to thrust the arm outward to the rupturing point. In several cases the *fastenings* were found inadequate to hold the beam and arm together, although placed in about equal quantity, size and distribution to the proportion commonly used in vessels. It should be remarked, however, that the (grown) knees were of better than ordinary quality, and were all prepared in the Navy Yard.

RESULT OF TRIAL.

No. 1. Bent knee, sided 10½ inches, moulded 10 inches at the throat, the remainder of size in throat made up of chock on the corner; angle of knee, 95 degrees; power applied, 5.37 feet from corner of arm; and fulcrum at right angles with a point on the body, 1.92 feet from corner:

Bent inward at	½	inch, required	5,500	pounds.
" "	1	" "	7,500	"
" "	1½	" "	8,500	"
" "	2	" "	10,000	"

No. 2. Natural, or grown knee; sided 10½ inches, moulded to corner; angle, 96 degrees; power, fulcrum, and fastenings same as No. 1.:

Bent inward at	½	inch, required	3,500	pounds.
" "	1	" "	5,500	"
" "	1½	" "	7,000	"
" "	2	" "	9,500	"

No. 3. Bent knee, sided 10½ inches, moulded 11 inches at throat, and filled out to corner with chock; angle, 88 degrees; power applied as in Nos. 1 and 2; fulcrum at middle of throat, fastenings as before distributed:

Bent inward at	½	inch, required	5,500	pounds.
" "	1	" "	9,500	"
" "	1½	" "	10,000	"
" "	2	" "	11,000	"

NOTE.—This knee (No. 3) was bent inward six inches, without apparent injury, when the fastenings giving way, the knee was allowed to return, which it did, was refastened, and again bent inward, when it sustained within about nine per cent. of its first pressure without fracture.

No. 4. Natural or grown knee, sided 10½ inches, moulded to corner; angle, 90 degrees; power applied, same as to those before bent; fulcrum at middle of throat, as for No. 3:

Bent inward at	½	inch, required	5,500	pounds.
" "	1	" "	7,500	"
" "	1½	" "	9,000	"
" "	2	" "	10,500	"

No. 5. Bent knee, sided 10½ inches; moulded 11 inches; filled out to corner with chock; angle, 90 degrees; leverage as before (5.37 feet from corner); fulcrum at right angles from middle of throat, 3.08 feet:

Bent inward at	½	inch, required	8,000	pounds.
" "	1	" "	14,000	"
" "	1½	" "	18,000	"
" "	2	" "	22,500	"

NOTE.—This knee (No. 5) was bent outward 10 inches without the least rupture, and the stress equaled 37,500 pounds, and on being relieved returned to within 4½ degrees of its former angle, when it was again subjected to pressure, and when at 11½ inches from its relieved position, the stress amounted to 36,000 pounds, (but no rupture occurred).

No. 6. Natural, or grown knee, sided 10½ inches, moulded to corner, full and well-grown, with 5 feet arm, the very best the Navy Yard or market could furnish; angle, 82 degrees; fastenings, leverage and fulcrum as before applied (to No. 5); one inch larger in body than bent knee No. 5 at commencement of throat. This knee had two trials, in consequence of the necessity of re-arranging to secure equality of position. (What was the inequality is not stated.)

ON FIRST TRIAL.

Bent	inward at	½	inch,	required	7,500	pounds.
“	“	1	“	“	20,000	“
“	“	1½	“	“	26,500	“
“	“	2	“	“	33,000	“

ON SECOND TRIAL.

Bent	outward at	½	inch,	required	11,500	pounds.
“	“	1	“	“	22,500	“
“	“	1½	“	“	31,500	“
“	“	2	“	“	38,500	“

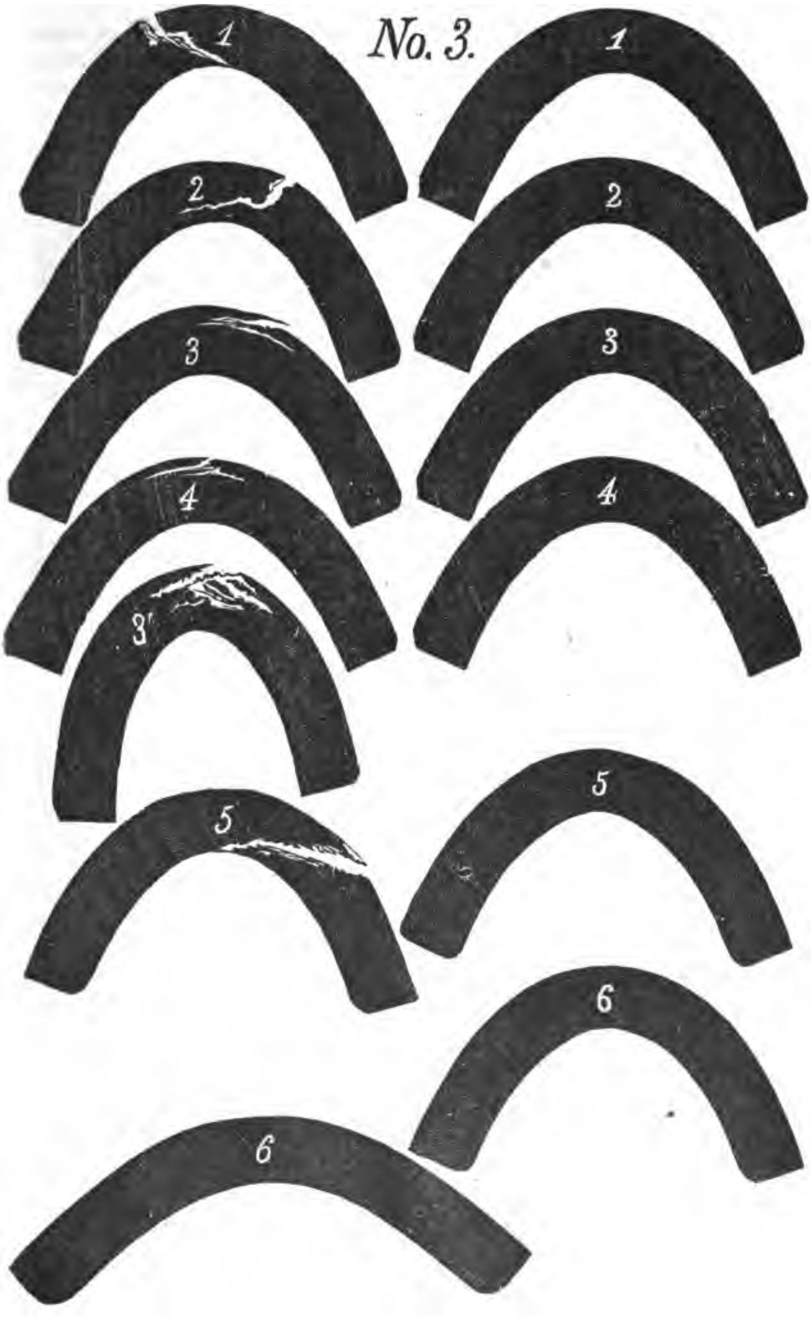
It broke at two inches in the throat, the rupture being complete. We have not extended the account of these tests beyond two inches, inasmuch as the best *grown* knees rupture at that point. (*The bent knees were not ruptured at any point*).

Before these experiments were made, few could be persuaded that bent timber, and particularly bent knees, could be made available for nautical construction.”

The result of this trial of machine-bent, with the best grown knees, established the character of the former, and accordingly a favorable report was made by the commission to the Navy Department. In the following year some of the best known ship-builders of New York, among them Messrs Webb & Bell, Jabez, and E. F. Williams. and Wm. H. Webb endorsed the use of machine-bent timber to the Government. In 1858 the U. S. Steam Sloop-of-War *Pawnee* was constructed at the Philadelphia Navy Yard, and in her frame about sixty machine-bent timbers, from 20 to 24 feet long, were used, being distributed where the greatest and most difficult curvatures in the bilge, amidships, were required. Her hanging knees, inserted between the frames and alongside the beams, were also of white oak. (With the exception of the white oak bent timbers and the knees, the Pawnee's frame was live oak).

The averages of the results of the two sets of trials for the *inward*

No. 3.



strength, the extremities of the knees being forced together, will compare as follows:

	Natural Knees.	Bent Knees.
Bent inward ½ inch, required	4,500 lbs.	6,000 lbs.
" " 1 " "	6,500 "	8,500 "
" " 1½ " "	8,000 "	9,250 "
" " 2 " "	10,000 "	10,500 "
Totals of averages,	29,000 "	34,250 "

From which it appears the average total superiority in strength of bent over natural knees is *fifteen* per cent., and for the first half-inch of movement the superiority is *twenty-five* per cent. in resisting an inward stress, such as is *the most trying for hanging knees.* This result is just what might be expected from the bending of the bent knee, the process having compressed its fibres into *solid* wood in the throat, in which it would take a microscope of large magnifying power to detect even the traces of the capillary vessels. The root is the strongest part of a tree, but its fibres cannot grow solidly together; there must be duct and cells throughout the wood for the circulation of sap and fluids. Increasing the solidity of the wood undoubtedly accounts for the improvement of quality which results from the machine-bending of knees, whereby the wood of the upper part of the trunk of a tree, though having less strength than the root, upon being forced into the form of a knee develops equal or superior power.

In the trial of No. 6 against No. 5 for the *outward* strength, the advantage was in favor of No. 6 up to the breaking of the latter at 38,500 pounds, but this was probably owing to superiority of size or quality of timber, rather than the condition of natural growth. The bent knee did not break, although it sustained six times the movement of its competitor, and bore a stress of 37,500 pounds, and afterwards of 36,000 pounds without showing the least signs of fracture. It cannot be doubted that the ultimate strength of the bent knee was fully the equal of the grown one. And in length of arm and consequent room for fastening, by which alone the strength of knees is made available, the bent knees were undoubtedly the best.

The following tests of bent and natural crooks have been made at the International Exhibition:

The pieces of wood were nine inches long, half-inch thick, and one inch wide, or sided one-half and moulded one inch. Referring to the accompanying cut (No. 3), Figs. 1 and 2 represent the natural crooks, and Figs. 3 and 4 the bent pieces. The force of the testing machine was applied to the points of the crooks to close them together. The pressure of 500 pounds was put on each piece shown in the second column, with the results shown in the figures of the first column. No. 1 was absolutely broken in two parts; No. 2 was broken across three-fourths of its section; and, in contrast with these destructive fractures, No. 3 was only cracked across one-eighth of its section, and No. 4 across three-sixteenths of its section. No. 3 was afterwards submitted to a pressure of 790 pounds, which caused a fracture of three-fourths of the original section, thus showing the great superiority of the bent crook.

To complete the tests for the cross strength two trials were made to break the pieces, which were seven-eighths of an inch square, in the opposite way, viz: by separating the points, and with the following results:

The bent piece (Fig. 6, second column) *could not be broken,* but developed a strength equal to 1295 pounds pressure, at which the effect was to straighten out and not to break, as shown in the first column. The natural crook (Fig. 5) broke completely across its section with 1305 pounds pressure. This experiment shows that it takes about as much power to straighten out a bent crook as to break a natural one.

Tests for the tensile strength were then made in the following way: From the same piece of white oak nine specimen pieces were prepared, each ten inches long and one inch square. The section in the middle of three of them was reduced to half-inch square by curving it on all sides. The average breaking strength of these pieces (of *Indiana* white oak) was equal to 18,500 pounds per square inch. Three pieces were steamed and bent to a right angle, as for knees, and reduced in section at the middle and broken by tensile strain. The average strength of these pieces was equal to 18,510 pounds per square inch. The remaining three pieces were steamed and bent as the three preceding, and were afterwards resteamed and straightened out, and then tested for loss of strength in straightening from the bent form. The straightened pieces were broken at an average of 14,680 pounds, showing that the bending process when properly executed is not injurious to the *tensile* strength of timber, and only so when a double or reverse operation has been performed, and then only to the extent of twenty per cent.

It should be observed that the fractures in bent wood never run slanting across the grain, as in the wood of natural crooks or straight pieces. The separation of fibres is square to the curve, and there is no damage to the remaining wood by oblique cracks and splits. The broken grains may be removed, and the wood remaining will be as strong as ever. Natural crooks, particularly those from limbs and roots, differ from bent crooks in having less flexibility and elasticity and more stiffness, but this stiffness renders them more liable to fracture under a stress.

THE DURABILITY OF BENT TIMBER.

Following the tests of "bent and grown knees," by the Naval Commission in 1856, machine-bent futtocks and knees were fairly introduced at the port of New York. The bark *Lexington,* built by Edward F. Williams, in Brooklyn, was the first vessel to use a full set of bent hanging knees. Very soon after the building of this vessel she was subjected, in the tropics, to one of the severest practical tests of the excellence of her construction. The weather was so stormy that thirty days were spent on the passage from Havana to New York. Her builder thus expressed his views on the utility of bent knees, in a letter to the President of the Timber Bending Company: "I yesterday was on board the bark *Lexington* built by me, and whose hanging knees are of bent timber furnished by you; and, with the exception of ordinary shrinkage, found them as perfect as when I launched the vessel (four months before). She sailed from this port early in September last, for Mobile, and thence to Havana, where she took in a full cargo of sugar and tobacco for New York, where she arrived about ten days since, after having encountered very heavy weather. The condition of those bent knees, after the severe trial they have had, having been exposed for some time to the extreme heat of the tropics, and with a heavy return cargo and tempestuous weather, confirms me in my former opinion of their good qualities and suitability for any position in a ship where white oak knees are required." Ten years later the *Lexington* was rebuilt; her bent hanging knees were then unimpaired in strength and soundness, although the natural-grown timbers to which they had been secured had gone to decay. *All the knees were saved and used again.*

In 1856, also, machine-bent knees were exclusively used in the construction of the bark *Jane Dagget*, built by Webb & Bell, at Greenpoint. Being convinced of the superiority of the bent timber hanging knee, the owners of the *Jane Dagget*, Messrs. Dunham & Dimon, preferred them for both upper and lower deck-beams. Many of these knees were ten inches in thickness, with long, squarely-developed arms and in strength and finish they challenged the commendation of all who saw them in the ship. The *Lexington* and the *Jane Dagget* have both been lost, and it cannot, therefore, be known how long their knees would have lasted.

The ship *Richard S.. Ely*, built at East Boston in 1858, was another vessel to use bent hanging knees. She was repaired largely in 1866, amounting almost to rebuild, being found on survey extremely rotten for a vessel of her age. Only in a comparatively few cases of the upper deck knees was the bent wood in the least affected by the surrounding decay, although the chocks on the corners of about half of the knees of this deck had suffered more or less with the other unsteamed and unbent wood to which they joined. Had these knees been wholly of steamed and bent wood, properly cured, it is not to be doubted that every one of them would have been found perfectly sound. It is not affirmed that well-bent wood will last forever, but that the process which it necessarily undergoes is one highly preservative in its nature. It is believed that *in no case has it been found that rot has originated* in a stick properly steamed and well bent by the end pressure process.

As for the durability of bent futtocks, it may be asserted that, so far as known, none have yet been found decayed. The first pair ever used were put into the steamer *Ocean Bird*, built by John W. Griffiths, in 1853. The steam sloop-of-war *Pawnee*, by the same builder, in the Philadelphia Navy Yard, in 1858, had about sixty futtocks from 20 to 24 feet long, of bent white oak. These were the *longest* futtocks ever used up that time, and were intended to give increased strength to the bilge amidships, it being impossible to find live oak of sufficient length to make these timbers in one piece. These bent futtocks are yet *sound*, not one of them having to be removed because of any defect, after a most thorough search for rot throughout the vessel, at the Kittery Navy Yard, in 1869. It may be added that the *Pawnee* has served more time, in proportion to her age, on the Gulf station, or exposed to a tropical climate, than any other vessel in the service. Her hanging knees, which are of white oak, are placed between the frames and on the sides of the beams, and no vessel in the service, of her tonnage, carried a heavier battery of guns on her deck during the war. Her white oak knees were in *sound* condition when examined at Kittery yard.

In vessels that are *salted*, the placing the knees between the timbers will be found highly condusive to their durability. As hanging knees are usually applied *under* the beams, it is not possible to salt them sufficiently for their preservation without boring holes into and weakening them. As vessels are now built, the knees are never salted, and often speedily decay; besides, they are from roots and limbs, *sappy*, and in need of special preservation. By placing the knees, whether grown or bent, between the framesand alongside the beams, and working the clamps inward to form a shelf, the knees may be salted and preserved as long as the planks which enclose them, *and if bent they will last longer.*

HISTORY OF TIMBER BENDING.

With the evidences of the utility of the ship timber bending machine before them, many persons have inquired why its use has not become general in the shipyard? The reasons are well known to but few. From 1856, and for about two years thereafter, machine-bent timber supplied by the only mill in existence, was more or less used by the best builders of New York, and but for the panic of 1857, the consequent decline of shipbuilding, and the mismanagement and failure of the company holding the patents, it would no doubt have been introduced in other ports, notwithstanding the machine, as an invention, was very crude and imperfect, and its operators unskilled in the work. The affairs of the company were managed by gentlemen who imagined that wealth was to come from *stock* operations instead of from the perfection of the invention. It might be explained at length, were it necessary, how, after bent futtocks and knees had been approved by the most competent authorities, and gladly adopted by the most enterprising shipowners of the metropolis, the deficiency of machines capable of producing the crooked timbers of the forward and after bodies of vessels, with the proper bevel wood, and in whatever length required, as well as conflicting interests among patentees, and the holders of patents, and, finally, financial embarrassments put a stop to the operations of bending ship timber. It was found that money would be needed for improvements to make the bending machine a financial success for shipbuilding purposes. The original inventor of the machine was not a shipbuilder, and seemed to have but one idea of its utility, viz.: to make short straight timber into *crooks*, looking to the difference in price for crooked over straight sticks for remuneration for his labor. He did not comprehend the capabilities of his invention, nor know how to make it of real value to the great art of shipbuilding. Short of an exclusive use of machine-bent timber in the frame of a ship, and the changes of system in building necessary to make that use of material value, it could not be expected that the shipping fraternity would everywhere welcome the invention as a success. In point of fact, only a few became aware of its existence. While the original patents were in force the building of machines by other inventors was impossible without infringement, as without the use of the metal strap to hold the back of the timber and give the end pressure, the bending could not be performed. Ultimately. the holders of the Blanchard patents gave up ship timber bending, and confined their operations to producing furniture, wheelwright and farming implement stock; or engaged in manufacturing enterprises in which their machine answered a better purpose than in shipbuilding, as it was then developed.

After passing through the hands of the American Timber Bending Company, and other parties of New York, the entire patent rights for ship timber became at last concentrated in the hands of its earliest patron, C. Allen Browne, Esq., of Boston, in 1864. Through the efforts of Mr. Browne all the formerly conflicting interests were finally reconciled. An extension of the patent was obtained, and new inventions in machinery and appliances were caused to be made and patented, so that all the curvatures necessary in a ship's frame may now be produced; the timbers can be beveled before bending, as required, and the frames may be *in single length from the keel to the rail.* It is, therefore, only from 1865, when the Union Ship Timber Manufacturing Company was formed, for the sole purpose of working out by invention and experiment the best practical mode of building a superior wooden ship by machinery, that we should date the commencement of rational efforts to make the bending machine really useful as a factor in a shipyard.

THE ADVANTAGES OF MACHINE-BENT TIMBER.

If principles were as influential as opinions, it would be an easy matter to reform an art like ship-building. Setting aside the perils of the sea arising from imperfect charts and improvident or reckless navigation—dangers not within the ship-builder's art to avoid—and considering those perils only which come within his province to provide against, it is evident that without shipping a sea, or springing a leak, sound, strong, properly loaded vessels would never sink. The former may be the result of bad model as well as overloading, wrong management, or loss of propulsory power; the latter is nearly always the consequence of faulty *construction,* either in materials or mechanism, though sometimes owing to excessive or badly stowed cargo. The responsible work of the ship-builder is to provide unfailing buoyancy by strength and tightness, as a certain means of preserving life and property on ships at sea. To ensure this, next to the choice of a good model, he must adopt the best method of erecting the frame. The function of the frame is to skeletonize the body of the ship and enable her to support herself ashore and afloat. Considering a ship's frame in its completeness, it will be seen that it combines a longitudinal and a transverse system—it must have back-bone as well as ribs, to enable it to perform its function. The longitudinal framing includes the stem and stern, keel, keelsons, deck clamps, shelves, stringers and the rail, together with binding strakes wherever worked. The transverse framing consists of all timbers erected crosswise the keel, including the beams and hanging knees.

The perfection of a transverse frame is its *unity*, strength, elasticity and lightness. Every transverse frame should be continuous round the vertical outline of a ship, not unlike a hoop around a cask. Every transverse frame should have the fewest possible number of pieces in it, and every complete single frame should have strength enough to bear its own weight on the keel without the support of shores. Of two frames, the one requiring most support in position is the weakest. Support is everywhere the mechanical index of weakness. Considering a ship's frame as the skeleton of her body, the outer skin and inner lining and decks should receive support from it. In proportion as the frame is weak, however, it must be helped by thicker skin and ceiling, diagonal iron strapping, and other means, thus adding to the weight and cost. The principal weakness of framing is in the transverse system. Vessels of wood, and of iron, too, have been built without transverse frames—a thickened skin doing duty as frame and skin in one. But, if not prematurely lost, such vessels have to be subsequently strengthened to be made seaworthy, and they are wholly unfit to take the land. The pumps will persist in revealing their weaknesses, and the frequent docking proves their incapacity to sustain their shape afloat or ashore. Experience in running vessels without due strength in transverse frames is as old as the art of navigation itself. Every old vessel whose frame has become *rotten* is an example of dispensing to a greater or less extent with the transverse frame strength, and while we will allow that it is surprising how little of *sound wood* will serve as frame timber to hold a vessel together, it is only necessary to note with what certainty they *spring aleak* in rough weather, to determine how dangerous it is to trifle with the strength of a ship in the transverse framing. We have seen vessels with sound and others with rotten frames dashed at the same time against a breakwater. The vessels with sound frames, though resisting destruction at first, yet were sunk after a time, but subsequently were raised and repaired. The vessels with rotten, and therefore weak frames, made only a momentary resistance to the violence of the sea, and a patch of drift-wood soon marked the spot where the unequal struggle took place. Going to sea tries the planking, but going ashore tries the framing with most severity. The fatal weakness of transverse framing is its composition of *short pieces*, of more or less *cross-grained timber*, put together with *short laps*.

An eminent British authority, Mr. J. Scott Russell, has laid it down that the best wooden ships are only to be built with "solid frames up to the lower deck," and this on account of the necessity for using short timbers in framing. Mr. Russell favors *iron* ship-building, although nothing in that art so plagues the builder as the working of the frames in continuous length. Deeming it impossible to make wooden as well as iron frames in continuous length, he rather enjoys the triumph of the iron over the wooden builder, and thus dilates on the situation:

"A single tree never furnishes an entire frame. (But it may). If trees could be found to grow to the right curves for complete frames, it would be glorious times for wooden ships. (Art can supply the deficiency of nature). The longer, however, they can be found, the better, and it is a sin to cut in pieces any part which can be well done in one; (ship-builders need "sin" no more). *Never, however, can a single tree be found to go round the vertical outline of a ship.* (How mistaken he is—a ship has been built since his writing with frames in "a single tree" from keel to rail on each side, 43 feet long, curved by machinery). I have seen bow frames made of as few as two pieces, but there are seldom less than a half a dozen pieces in a frame; (and generally a baker's dozen, he might have added), the frame thus formed is nowhere stronger than it would be if it could be grown (or bent) in one piece of *half* the size."

By all means let us have, as we may, the frame timber in one piece, from the keel to the rail, and have the frames for two vessels out of the trees for one. Russell alludes to a method of building up frames out of planks by bending them to the mould, and securing them together. "I have seen the frames of steamships in the dock-yards made and bent in this way, where great strength was wanted with great lightness, but, of course, it was a sorry substitute for continuous grown timber." Therefore, let us have the "continuous" timber, whether "grown" or bent, and, especially, as we may have it as strong by bending as by growth, and let the "glorious times for wooden ships" hasten their advent, for the increased security of life and property on the iron sinking deep.

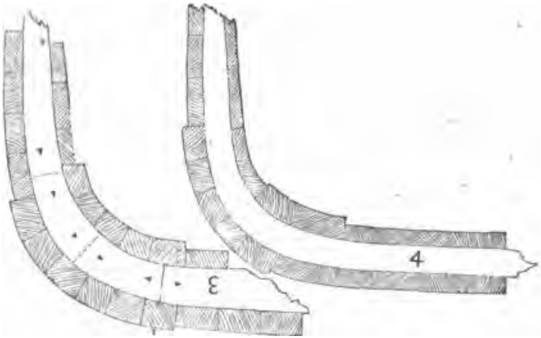
A frame of grain-cut timbers, in short lengths, must of necessity be larger in the moulding size than it need be if the timbers were grain-grown or well bent in single length from keel to rail, in order to have sufficient strength. This increased moulding has an influence to shorten the laps of the pieces of the short timbered frame, and thus one fault leads to the commission of another. In the bilge we see the culmination of the errors thus unavoidably made, in the large assemblage of thick strakes, and the immense quantity of bolts driven in the fruitless endeavor wholly to restore the strength which has been lost, *by first cutting the trees into short lengths, and then lapping them together and building them into the crooked forms of the frames,* at a great waste of material and labor.

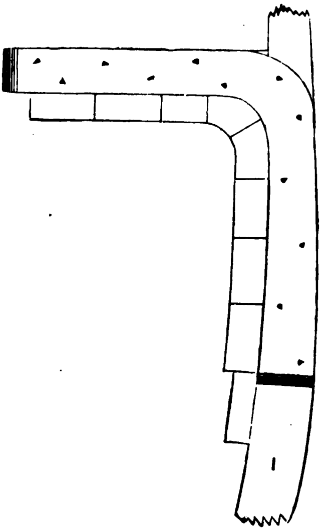
The use of machine-bent timber combines two advantages: first, none of the fibres in a stick being grain-cut. but all grain grown the machine lessens the quantity of timber required for construction, and what is saved from the frame may be added to the planking, giving the ship increased strength, both transversely and longitudinally, out of the same stock of material. Second, the moulding size and weight of the frame being decreased, the cost of the ship will be diminished, and the cost of bent timber being less than that of timber in short crooks lapped and bolted together, there is not only a saving arising from diminution of quantities of timber used, but also a positive saving resulting from diminution of price of that quantity. It results that ships for less cost may have greater strength and greater buoyancy. They will also have exemption from the evils consequent upon the working apart of the pieces composing the built-up frames. By having continuous timbers free from butt joints, the ship will have an *elastic* frame, and so resist the shock of a sea as best to distribute the effect over the hull instead of concentrating it on some weak spot, as the bilge, whereby a leak may be caused. The planks now often meet timber butts several times in a single strake, and as butt ends of timbers will not bend, but will project, the planks are in consequence liable to be worked from the frame in the straining at sea, an effect which is invariably made known at the pumps. The caulking will be much more firmly seated in the seams, where the planks are laid over continuous timbers, than in *piece-frame* ships. The caulking should be as firm as the edge of the planks which make the seam, but now the proper driving of the oakum tends to, and generally does open the butt joints of the short-timbered frames, making it a farce to have ever fitted them closely. The ship of continuous timber frame may have the stronger caulking, and the frame may be fully relied upon to hold it. And a ship so framed will require less re-caulking in her life time, besides being tight under circumstances where short-timbered ships would be sure to leak.

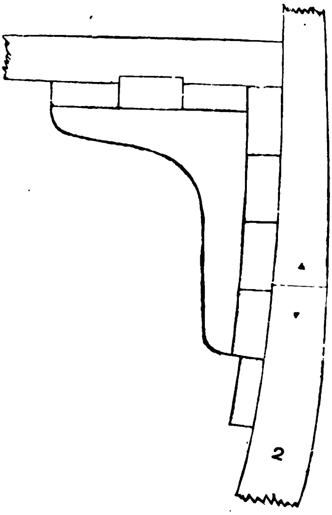
But it is not only at sea, that the vessel of continuous frame timbers would be the safer from the admission of water to the hold. The facility with which collisions with the bottom now knock in the bilges of vessels is mainly due to the closer lines of butts in the region of greatest exposure between the bottom and the side. When old ocean shakes his mane and sets up his defiant roar, pity the poor ship cast upon the coast! Short work is made of her destruction then—the wrights who raised her *ribs* sawed them up, as a butcher prepares a roast!

It should never be ignored that the trees out of which were made the timbers in the bilges, which now break up so readily, were once *long*, and that the shipwright only sawed them into short sticks and lapped them together again, because he had no means of bending them in full length, to the curve required. If he could not have bent his planks, he would have had to saw them short, too, and work them across the grain like the timbers. And many a ship's bow and buttock has been disfigured by splintered and broken plank, that the builder had no proper means for bending. And the case has been worse with the inside planking, which has often been scored with an axe to make it flexible. Then, what waste has been in cutting wide planks down to narrow ones, to get curvature by cutting across the grain. All which may be avoided by the proper use of a bending machine. The same machine which bends the timbers of the frame will bend the logs for the planking, or the plank themselves. It will also bend keelsons, stringers, clamps, shelves, waterways, planksheers, rails and chocks; while the knee machine will bend floor timbers, sharp rises, breasthooks and knees.

The accompanying cut, taken from Capt. E. P. Dorr's Rules for Ship-building, Buffalo, 1876, illustrates the improvement in bilges and hanging knees, rendered feasible by using bent frames and knees. It will be seen that the inside bilge strakes are reduced to two in number in consequence of the frame having no butt joints in the bilge, and the hanging knees are placed where they belong in the framework of the vessel, where they make a *direct* connection with the beam and top-timber, binding them more firmly together. The beams and knees are raised with the frame to which they belong, each beam having a pair of knees at each end. By this system the clamps are worked after the beams are in, and are turned inwards to form a shelf, the strakes being doweled and bolted edgewise, as well as in and out and up and down through the knees, beams and top-timbers, making the strongest possible connection between the side and the deck, and keeping the knees from obstructing the stowage of the hold. Lodge and bosom knees are dispensed with, as having been superceded by the edge-bolted shelf.







Every useful sort of timber, whether of our own or foreign countries, may be bent by the bending machine. Some kinds of wood will work better than others, but most kinds will act well enough to bend into forms for knees. All the oaks bend well. Live oak is rather stiff, owing to its gummy nature, but it may be bent into knees. Second growth wood is not so flexible as that from the forest, and knotty timber requires skillful treatment, but it only requires a knowledge of bending, such as may be gained from practice, to determine how best to get a bent frame out of a given stock of timber. Any shipwright who can work steamed plank skillfully can soon learn to bend frames and knees. It is not within the compass of a pamphlet like this fully to describe all the processes of machine-bending. As to the number of sticks that may be bent in one day, on one machine, it depends upon the size of machine and of the timbers, the facilities for steaming and handling the pieces, and the activity and skill of the workmen. Two pieces are always bent at once. Six men ought to saw, steam, bend and put together one frame, with beams and hanging knees complete, in one day for a vessel of 1000 tons. The timber would consist of one floor, two long futtocks, eight knees and two beams. Or, the same force may bend the timber for four frames in a day for a ship of any size. For smaller vessels the work can be done faster, the timber being given less time to stand in the machine, and being more easily manipulated. Sixteen first-class perfect 9-inch knees have been bent in a day of eight hours.

To sum up, the advantages of machine-bent ship-timber may be thus stated:

1st. Economy of frame timber, by the reduction of waste in hewing or sawing out the shape, and the bending of straight-sawed or sweeping pieces of any size and form required.

2d. The supply of stronger and longer crooks for every part of the frame.

3d. The supply of knees with longer arms, without wane and sapwood, of tested strength, superior to those of natural growth.

4th. Avoidance of grain-cut timber in frames or planking, and rejection of unsound pieces. In bending, only sound and perfect timber will produce good knees and short turns, while naturally grown crooks are often afflicted with some imperfection more or less serious.

5th. The prevention of dry-rot by the changes effected in the condition of the wood, by steaming and bending under pressure.*

6th. Partial removal of the corroding tendency of the wood upon its metal fatenings.

7th. The strengthening of ships, by the use of longer pieces and fewer of them in the frame; also, increasing the elasticity of vessels, by the disuse of grain-cut timbers in short lengths with numerous lines of butt-joints, particularly in the bilge, and sensibly enlarging

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*NOTE.—Boat timbers bent without the application of *end-pressure*, and strained on the back, are liable to rot prematurely in the strained place, but by the process of machine-bending such timbers would be rendered stronger instead of weaker, and more instead of less durable in the place where most curvature is given.

their capacity and burden by reducing the scantlings and weight of the frame.

8th. Saving of cost. Good crooks are a scarce material, costing the double of straight pieces; they can be bent for less than the difference in price; and, in length, durability and quantity unlimited in comparison.

9th. Enhanced safety to life and property, by greatly reducing the liability to spring *aleak*. Ships' frames may be bent as boat timbers now are, the entire length from keel to rail in one piece, *forty to sixty feet long*, enabling a vessel to withstand the working of the oakum out of the seams and butts, and to endure much longer, or survive the shocks that would seperate into pieces a vessel of the common build.

BUILDING AND HISTORY OF THE "NEW ERA."

The origin of the first bent timber ship was due to the inspiration of philanthrophy. There was a merchant of Boston who went to sea when he was a boy, and suffered from a weak-timbered and leaky vessel. Time after time had he laid out on the yard arm, reefing and taking in sail, and upon his return to the deck, almost exhausted, *a spell at the pump* had to be taken. This he endured for twelve months, once putting into port for repairs, leaking badly. Once, on a passage from Pensacola to St. Thomas—65 days (!)—35 of which the ship's crew were on an allowance of one pint of water per day, and that brackish, 17 days of this time in the "Horse Latitudes," with not a breath of air sufficient to wave a cambric handkerchief, the pitch boiling out from the seams in the deck, with nothing to eat but raw salt beef and pork—the cooking utensils had been carried away—and biscuit so thoroughly eaten by worm and weevil that it could be blown to pieces like down from the thistle flower—three and five feet of water in the hold a portion of the time. For many years that *pump handle* was a nightmare to this young sailor boy, and often in his dreams he worked those never-to-be-forgotten scenes over and over again, until he awoke nearly exhausted.

Time sped on and fortune blessed him in his industry. Then it was that a monitor came knocking at his door. The world has blessed you; *in what have you blessed it?* The question was answered in the usual way of grateful and kind-hearted men, but that way of answering would not entirely quiet the gentle knocking. The question came in another shape. In what has the world been made *better* by your having lived? Lovingly you were born into it, and have partaken of its blessings. Those who lived before you fitted and prepared the world and society with luxuries, enjoyments and safeguards; you could not have partaken so bounteously of these without their work, ingenuity, foresight and much sacrifice! This serious question had to be fairly and squarely met. His early sailing experience could not be forgotten—his sympathies were naturally with the scenes of his youth. His desire was *to help the sailor*, and make all who live and travel on the mighty deep feel more safe, and be more secure from the hardships and dangers of the elements. Then it was that the improvement of ship-building, *by the bending of long timbers*, and the building of ships *stronger*, *tighter* and *safer* than ever before, came to his relief.

But the proposer of this duteous benefaction was not a ship-builder, not a mechanic, even, and knew nothing practically about machinery. What could *he* do? He could purchase the patent rights for bending ship timber, and then seek for a skillful architect and practical ship-builder, who could contrive the machinery necessary for building a bent frame ship. This he did. He sent for Mr. John W. Griffiths, explained to him what he desired to accomplish, and secured his services for the task in hand.

Thus was the work of C. Allen Browne undertaken. The alliance with Mr. Griffiths was a most happy and fruitful one. As the story of the steam engine cannot be told without mentioning in succession the names of Newcomen, Watt and Boulton, so neither can the history of the bending machine and the first bent timber ship be recited without acknowledging in their order the claims of Blanchard, Griffiths and Browne. From the first it was determined that every stick in a ship's frame should be sawed from the log, be beveled and bent to the mould by machinery, and that timbers in one length should reach from the keel to the planksheer or the rail. The beams of the decks were to be treated as belonging to the transverse frame system, and therefore to be kneed directly to the toptimbers in the firmest and most secure manner. Not a few difficulties presented themselves, but all were surmounted in the end. Working models of the bending machine were first made. Devices were changed, improved and perfected, and miniature ships were built to test the success of the invention in its various stages. As an instance of the perplexities that were overcome, it may be related that it took twenty-two trials to discover how best to make a certain compound bend.

Having successfully worked out on a small scale the new system of timbering ships—henceforth to be known as the bent timber system—in was determined next to build a full-sized bending machine, and produce the largest required full-length frame timbers. This, too, was successfully done. Then it was thought by Mr. Browne that his work of marine benefaction was fully accomplished, and that the world would accept it as a wonderful triumph in art, and commence at once to build ships on the improved system—the capacity, strength and power of the machinery being ample for all requirements. He was mistaken. As is was with Elias Howe and his first sewing machine, when he publicly demonstrated that he could out-sew *five* of the best seamstresses in Boston, and not a tailor in the city would purchase one, so it was with C. Allen Browne and the introduction of the bending machine. The ship-builders of Boston were astounded at his success, but unprepared to acknowledge it. They had always doubted whether large timbers could be successfully bent, and now that the error of their opinions were rendered manifest they could not be convinced. The more probable it appeared that the bending machine would one day revolutionize ship-building, the more numerous became the disbelievers in its utility. You have made *models* of bent timber ships, and bent a few sticks, they said, but now let us see you build a ship!—you can't build a ship, and if you do, she will not stay built, but will come to pieces!!

Up to this time Mr. Browne had expended individually upwards of $100,000. He had retired from active business. He did not want a ship, nor a ship-yard, nor a factory for machine-building, nor to do aught else than to cause the bending machine to be perfected, that thereby the mariner and the passenger by sea might have stronger, tighter and safer ships to sail in, whence the drudgery of the *pump-brake*, and the fear of *springing aleak* might, if possible, be forever removed. Many kind friends volunteered advice that a small vessel be built at first—in fact, they had also advised the building of a smaller machine—but the provoking doubts expressed as to the praticability of his noble intentions only effected the result of increasing his confidence in the merits of the invention; and, together with his associates, Messrs. Glidden, Williams and Ross, gentlemen of fortune, who shared in the noble enterprise, the resolution was taken to build a two-decked ship for the East India trade, and thus make a final demonstration of the advantages to be gained by the use of a bending machine as a *tool* of the ship-yard. It was fortunate that the promoters of the improved system were able and willing to prove their faith by their works, or the world might never have had to consider the character and history of a bent timber ship.

When the "New Era" was building she was the wonder of Boston. Every frame timber—some of them *forty-three* feet long—every floor, sharp rise, knee and hook was bent. Even to the rails, forward and aft, and the chocks thereon, were bent—of white oak timber. None could justly find fault with her design or construction, though none were willing to accept the new style as an example. All had to admit that bent timber was the *ne plus ultra* for frames—that steam ship-building in wood was a fact accomplished, *provided*, however, that the bent timbers did not some time become straight again! The "New Era" attracted many visitors, amongst others, many officers of the Navy; and the Navy Department required the constructor of the Charlestown yard to visit the ship frequently, and report fully as to the utility of the system and the efficiency of the machine upon which she was built. It may be added, that both the principle and practice of the new construction was approved by this intelligent and independent officer.

The "New Era" was finished in May, 1870, at a time when there was no encouragement to any one to build another American ship, and particularly a wooden ship. It is the opinion of her designer and builder, that no ship afloat, wood or iron, having no greater general dimensions, can carry an equal bulk of measurement or dead-weight cargo, on an equal draught of water, a given distance in equal time, under the same or similar circumstances of wind and weather, with an equal area of sail, and develop the elements of strength and seaworthiness in equal degree. The following letter is expressive of the opinions of three of the owners for whom the ship was built:

Boston, March 17th, 1870.

Mr. John W. Griffiths,

Dear Sir—The undersigned owners of the ship "New Era" have much pleasure in stating that they are entirely satisfied with her construction. Your success in bending her frame, knees and hooks has been complete, and we have no hesitation in saying that in our view (and we have had much experience in such matters) the "New Era" is the *strongest* ship ever built. And because of her superior ventilation, and from the fact that her timbers are thoroughly seasoned by the process of bending adopted by you, we feel confident that they are secure from rot.

Wishing you success in your efforts to extend and develop this *new era* in ship-building, we remain your obedient servants,

Glidden & Williams.
M. D. Ross.

The first Captain who commanded the "New Era" communicated his views of the ship in the following letter:

Boston, October 26th, 1870.

John W. Griffiths, Esq.

Dear Sir—In reply to your note of the 17th inst., making inquiry in regard to the performance of the ship "New Era" while under my command from Boston via St. Johns to Liverpool, I am pleased to state that so far as I was able to determine from a summer's passage across the Atlantic, the ship performed in every way perfectly satisfactory.

Commencing in the order of your inquiries, I will first state that I could not fully determine how great were the advantages of the outstanding *bilge keels*, as at no time did we have a whole sail breeze, and the ship being very stiff I could not judge if they were greatly beneficial in making her more weatherly. I am quite satisfied, however, they were a very great benefit to make the ship more easy in *rolling*. We had fully 150 tons more ballast than the ship required, and that, copper ore, taking up but little room compared with stone ballast, and stowed on the skin. Of course, with this excess of weight so low down the ship would roll very deep in a heavy swell without a corresponding wind. But she rolled remarkably easy, which was always noticed at such times by my officers, as well as myself. Nor am I of the opinion of some, that the keels (three in number on each bilge) were an impediment to the ship's sailing. The ends of the keels were so gradually tapered and sharpened, they could offer but little if any resistance to the water. I think the ship *sails well* for one of this model, designed for burden. On our passage to St. Johns, you yourself saw that with considerable less than a whole sail breeze, and that nearly aft, the ship ran *eleven and a half knots* off the reel, with little or no commotion, leaving behind a smooth and beautiful wake, apparently not going two-thirds of this speed, and also keeping pace with a sharp Scotch *iron* clipper in company with us, also in ballast and bound to

St. Johns. Nor did the ship move sluggishly when loaded down to 21 feet, the track on the chart showing long strides for five or six days in succession, with not a whole sail breeze; but with rougher water and heavy swell, making upwards of 200 miles a day, the speed varying from six to ten knots, and scarcely a drop of water coming on board, and very buoyant forward and aft. [The ship has very little sheer].

In regard to having no bowsprit, but jibboom only, it is true there was some cause to fear the ship would not have sufficient head sail, but I experienced no difficulty in this respect. With ordinary watchfulness, *she both steered and stayed well.*

Of the ship's carrying *capacity* it seems hardly necessary for me to speak, for it is plain to see that much room is gained by having the knees placed at the sides of the timbers and beams, out of the way of stowage, especially for stowing a cargo like deals or timber. We had under deck about 410 standard of deals (1980 superficial feet each), and 332 tons of copper ore—with the deckload, 30 standard more, the ship drew 21 feet. Probably we had on board upwards of 1500 tons dead weight.

Of the *strength* of the ship there cannot be the slightest doubt, nor did I hear any among the numerous scientific gentlemen who came on board, both at St. Johns and Liverpool, express any doubt on this point, but most of them seemed to be of a favorable opinion, and all admired the work.

We had no storms on our passage, but on two occasions we had three or four days of constant deep rolling, mainly caused, as I have previously stated, by having too much ballast, and encountering a very heavy swell with very little wind. This rolling was severe enough to try a ship a little, if not strongly built, but not the slightest appearance of straining could I discover in any part of the ship, though I examined most carefully. Trusting we shall hear favorable accounts of the ship from Calcutta in due time, I remain

ELIAS D. KNIGHT.

LETTER OF A BOSTON PILOT.

BOSTON, Oct. 25th, 1871.

MR. JOHN W. GRIFFITHS,

Dear Sir—In answer to your inquiries touching the sea qualities of the ship *New Era*, I would state that in piloting this ship into Boston from Calcutta, and out on her present voyage to Bombay, I was surprised to find a flat, burdensome ship prove so fast and weatherly at 20 feet draught, outsailing and going to windward of our fast three-masted schooners. She steers remarkably well; her sail is well balanced, notwithstanding she has no bowsprit, but only a jibbom. Her weatherly qualities and speed are in a great measure owing to her bilge keels, without doubt.

W. R. LAMPEE.

About six years of history having been made for this ship, her builder wrote Messrs. Glidden & Williams for particulars of her performance, and received the following letter:

Boston, June 9th, 1876.

John W. Griffiths, Esq.

Dear Sir—In answer to your request for particulars in regard to the performance of the bent timber ship "New Era," constructed by you, we hand you the following letters and documents.

It has taken us some time to hunt up her record and put it in shape, but we think it is one you will be quite proud of. In a seperate paper you have an attested copy of the *surveys* upon the ship, etc., etc. We only add that our confidence in the "New Era" has been confirmed by her extraordinary record, by the high character she has obtained, both at home and abroad. Our own opinion now, as at the first, is that she is *the strongest ship afloat*, whether of wood or iron.

Glidden & Williams.

(Notarial Copy.)

Boston Underwriters' Surveyors' Reports.

(No. 1). Ship *New Era*, Captain E. D. Knight. Owned in Boston by Messrs. Glidden & Williams and others. Built at East Boston, May, 1870; 1146 76-100 tons. D. deck, half poop and trunk cabin; house on main deck and open topgallant forecastle. Draft, 20 feet. Iron and copper fastened; single bottom. Two chains, 90 fathoms, 1¾ inch each. Anchors, 3675, 3500 and 1000 lbs. Has iron pumps and bilge pumps. Masts are single sticks; has wire rigging. Keel is gum wood, 12x20 inches, in 4 pieces; it forms the lower stem. The stem and apron are white oak; the apron is in one piece. The sternpost is white oak. Frames are also of white oak, in one length from keel to gunwale and rail; moulded 13 inches and sided 11 inches at the keel, tapered to 6 inches at the planksheer; spaced 21 inches from centre to centre; the joint upon the keel is strengthened by a floor timber which crosses the keel and the floor of the ship. Her plank are all yellow pine; two strakes of garboard, 8 and 7 inches; thence to the wales 5 inches; the wales are 6 inches. Has three bilge keels, 25, 35 and 40 feet in length, kept asunder by one strake of planking. The upper deck beams are yellow pine, 7x10 inches, 21 inches from centre to centre, secured with two hanging knees of oak, [sided] 5 to 6 inches in the throat with 4 foot arms, [at each end of beam], and bolted on the side of beams [and timbers] with 5 bolts in each arm [and body]; one strake 5x14 inches, bolted to the [under] side of beams; one clamp 6 inches, 4 strakes 5 inches and one of 6 inches. The upper and lower strakes are scarphed, and all thoroughly fastened with blunt bolts, plugged, and through locust treenails. Lower waterways 12x13 ins., bolted in each timber. Deck strake 6x12 inches, clinch bolted in each timber. Large hook forward and aft. Has iron stanchions with yellow pine stringer over their heads, 6 inches square, their feet resting upon a yellow pine sill, 8 inches. Lower beams yellow pine, 7½x 10 inches., 21 inches from centre to centre, secured with oak hanging knees as above. Yellow pine stringer 6x12 inches, bolted to the ends of beams. Ceiling is all yellow pine; 8 upper strakes 6 inches, thence to floor ends 8 to 9 inches, nearly all scarphed, and all thoroughly fastened with blunt bolts, and through locust treenails, averaging about 4 fastenings each timber, beside the copper butt and bilge bolts. Has two heights of yellow pine keelsons, 15 inches square each, with 4-inch oak cap. Sister keelsons 12x13 inches. Yellow pine stanchions 6x12 inches, 5 feet apart, and clamped with iron at the top and bottom. Two pairs of diagonal pointers, with large hooks in their throats, at each end of ship, in lower hold. Her iron fastenings are from ⅞ to 1¼ inch. The bilge keels are bolted with 1⅛ inch copper each 3d timber, and galvanized iron counter sunk and plugged in each timber. Has double angle iron bolted on the under side of the beams abreast of the main and after hatches. All her frames, hooks and knees are made of straight timber, steamed and bent to the mould. Has no joints in the frames from the keel to the rails. Every part is beveled and fayed to a snug joint, and the workmanship throughout is superior to anything we have ever seen in ship-building. Her length at load line is 183 feet; breadth, 38 2-12 feet; depth, 23 4-12 feet; height between decks, 7 1-12 feet. She is a very good model; has large capacity for cargo, and we think will sail fast. Is well ventilated and salted. Her rails, planksheers and upper-deck waterways are all very large and finished in the best manner. We think her a very strong, and in all respects a superior ship. Rate, A 1.

Boston, May 7th, 1870.

(Notarial Copy.)

(No. 2). Ship *New Era,* Captain Charles Babson, is now recaulking outside from metal up. She has just delivered a Calcutta cargo in splendid order. Her metal is slightly wrinkled, but there are no signs of strain or move to be seen about rails, or inside. She appears tight, staunch and strong. Is a good vessel. Yellow metalled September, 1870. Rate, A 1.

Boston, July 21st, 1871.

(Notarial Copy.)

(No. 3). Ship *New Era,* of Boston, Captain Charles Babson, now at this port, is said to have been stripped bottom, caulked and remetalled over felt to 20 by 21½ feet, with 20 and 28 ounce metal, in May, 1872, at Mauritius, where she put in leaking, having struck a wreck coming down the Hoogly river, which injured her bottom plank, causing her to leak. She now looks in fine order, is tight and has delivered her cargo of Calcutta goods in very fine order. RATE, A 1.

BOSTON, September 9th, 1872.

{ SEAL. }
R. G. F. CANDAGE, }
EBR. DAVIS, } Marine Inspectors.

(Notarial Copy.)

ADDITIONAL STATEMENT.

Marine Inspection Office.

Boston Board of Underwriters. { Record of American and Foreign Shipping.

BOSTON, May 10th, 1876.

This is to certify, that in addition to the entries upon the books of this office in regard to the *rating* and condition of the bent timber ship *New Era*, heretofore certified to, we have been conversant with the ship's performance through letters sent to her owners by those in her command, which have been shown us from time to time, and from what we personally know concerning the ship *New Era*, and what knowledge we have obtained concerning her from other persons, we have no hesitation in saying that it is our firm belief, that she has performed since the date of her construction to the present time, as well as any ship that we have any specific knowledge of; and that she is in all respects, as far as we are capable of judging, ***a first class ship.***

{ SEAL. }
R. G. F. CANDAGE, }
EBR. DAVIS, } Marine Surveyors for the Boston Board of Underwriters, and Record of Am. and F. Shipping.

(Notarial copy.)

TESTIMONY OF THE BOSTON LLOYDS.

BOSTON, August 24th, 1870.

JOHN W. GRIFFITHS, ESQ.

Dear Sir—Your favor of yesterday has been received. In reply, I beg to state briefly the grounds for the confidence Boston Lloyds have in the utility of bending the frames of ships.

There are the advantages of increased *strength* and *capacity* to the vessel. Besides, from personal observation the writer has become satisfied as to the durability of timber thus worked; and having noticed, while the *New Era* was being built, that a rotten piece of timber could not be bent successfully, even though the rot was concealed within the outside surface, we are thus assured that the ship has a sound frame at the start. The writer also saw for himself a satisfactory test of the durability of bent timber in the U. S. ship *Pawnee*, at the Kittery Navy Yard, when eleven years after her construction she was examined and thoroughly bored, and found sound, *not a piece of the bent timber* having to be removed. This ship's condition was in singular contrast to the *Wyoming*, built at the same time, and in the same Navy Yard as the *Pawnee*.* These facts were conclusive as to the durability of the frames so prepared, as well as the greater strength attained by the absence of joints in the frame, fully justifying a lower rate of premiums of insurance (*of nearly two per cent.*) at which the *New Era* was written by the underwriters of Boston.

P. W. PENHALLOW,
Attorney of Boston Lloyds.

ABSTRACT OF VOYAGES.

The *New Era* sailed from Boston on her first voyage June 1st, 1870, to St. Johns, N. B., in copper ore ballast, and thence to Liverpool, with deals and copper ore, arriving at Liverpool in 23 days from St. Johns, and ahead of the ship *Lucy S. Wills*, and other ships, sailing at the same time.

September 7th, 1870, sailed from Liverpool for Calcutta, deeply laden with salt, a particularly *dead weight cargo*, arriving out in 120 days, and ahead of the *Lucy S. Wills* and the *Elcano*. Loaded at Calcutta for Boston, at the highest rate of freight paid at that time, being insured for the voyage at an exceptionally low rate of premium.

On the second voyage she left Boston August 12th, 1871, for Bombay, with ice, arriving out in 102 days; thence to Calcutta—33 days passage to Sand Heads—beating all the fast *iron* ships 10 to 15 days. On the 24th of February, 1872, the ship left Calcutta for Boston. After leaving Calcutta, on this passage, a bad leak was developed, on account of which the ship put in at Port Louis, Mauritius, April 2d, and was there docked, when it was seen that she had struck and passed over a sunken wreck in the Hoogly river—the metal being torn off in places along the bottom, as well as from the stem, the sternpost and the rudder; some of the bottom planking chafed, a dent along the keel from about the step of the mizzen-mast, and the garboard seam open there, but no evidence of weakness or straining anywhere. After the damages named had been repaired, the surveyors for the underwriters pronounced the ship a first-class risk for insurance on hull or cargo.

Messrs. Israel G. Whitney & Co., of Boston, write under date of November 29th, 1872, to Messrs. Whitney Bros. & Co., Calcutta: "The owners of the *New Era* called on us, and say that the captain has with him certificates from the best offices, showing the ship to be A 1 in every respect. She insures at the lowest rates, and is in fine order. We know she has turned out her cargo both times from Calcutta in splendid order, and would give her the preference for our own goods. The leak last voyage, we are assured, was caused by striking on a sunken wreck, and had nothing to do with her peculiar construction, which is doubtless a great success. Your shippers need have no fear of the *New Era* landing anything but a fine cargo, and we trust she may get a high rate of freight.

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* NOTE.—The point of this comparison is in the fact that the *futtocks* of the "Wyoming," and the *bent timbers* of the "Pawnee" were *white oak*. The latter being steamed and bent were preserved, while the former rotted.

ISRAEL G. WHITNEY & CO.

Also, the undersigned underwriters of the American ship *New Era* are satisfied after the full examination of that ship by our Marine Inspectors, since the discharge of her last Calcutta cargo, that she is a *first-class risk*, and we have written on her at our lowest rates. The damage sustained on her late passage to Boston from Calcutta was, in our opinion, no way attributable to her peculiar construction.

Boylston F. and M. Insurance Company,
J. W. BALCH, President.
China Mut. Ins. Company of Boston,
(Insurers of freight of said ship),
FRANCIS BACON, President.
New England Mut. Ins. Company,
GEO. C. LORD, President.
Manufacturers Ins. Company,
SAMUEL GOULD, President.
India Mut. Ins. Company,
J. H. DANE, President.
Washington Ins. Company,
ISAAC SWEETSER, President.
Boston Marine Ins. Company,
R. B. FULLER, Attorney.

BOSTON, December, 1872.

On her arrival at Melbourne, in 94 days from New York, with 2055 tons of general cargo, the captain writes June 27th, 1874 (it being his first voyage in the ship): "The *New Era* has shown no signs of weakness whatever during the passage, and from her behavior should call her a superior ship in every respect. She sails very well for a ship of her capacity. Crossed the Equator 28 days out; had a poor chance across the S. E. Trades, and did not pass the meridian of Greenwich until May 17th. My greatest daily run was 275 miles; average 205 miles for fifteen days." Afterwards, he writes: "The ship turned out her cargo in splendid condition, so far as sea damage was concerned, not a stain of any kind—even the rosin on the bare skin was perfectly dry." From Melbourne the ship went to Sydney for coal, making the passage in 60 hours.

November 28th, 1874, the Captain reporting the ship loading wheat in San Francisco, writes: "Have had the ship caulked above the metal, as the Surveyors ordered. I think she will not require it again very soon—*it was like caulking a brick wall.*"

Upon his arrival at Dublin—in 125 days from San Francisco—before beginning to discharge, the Captain writes, April 21st, 1875: "The ship has behaved well on the passage, and has *made no water.*" After discharging, he writes: "The cargo, 1516 tons of wheat, was all turned out in good order; no damage whatever." At the commencement of this voyage just ended at Dublin, he wrote as follows:

SAN FRANCISCO, October 20th, 1875.

MESSRS. J. HENRY SEARS & CO.,

Gentlemen—Telegraphed you my arrival on the 17th, 48 days from Sydney, with 1440 tons coal. Run my eastern up to 153° W. longitude, and took S. E. Trades in 30° south, fourteenth day out; got them brisk; and, on the morning of the seventeenth day, passed the Island of Tahita. Crossed the Equator twenty-third day, in longitude 147° W., having averaged a run of 206½ miles per day for twenty-three consecutive days. Carried S. E. Trades to 8° N., and took the N. E. Tades in 13°; had them fresh, and lost them in 28°, having done this much of our passage in thirty-three days; thence had rather light, variable winds most of the time, with some calms. Made South Faralone at daylight, 16th inst., having been within 50 miles of it for thirty hours previous; had it calm that day and night; got breeze on morning 17th, and came in. At the time of our arrival, there was due from Australian ports eighteen ships which had sailed before the *New Era*—some of them out eighty days. One, the *Star af Bengal* (*iron clipper*), 159 days from Melbourn, *in ballast*, anchored with us.

The ship is in good condition, and will require very little here to go around the cape with. *Have never seen a ship show so little signs of weakness in hard driving, with a heavy head sea, as this one. She made no water* on the passage, sailed better than on the passage to Melbourne, although a foot deeper, being in better trim.

C. H. SAWYER.

Leaving Dublin, the *New Era* loaded 1461 tons of coal at Cardiff for Hong Kong—having first been re-metaled—and sailed thence on the 22d June. From Hong Kong, after giving account of the passage, the Captain writes: "Took a pilot at 4 P. M., 19th October. Anchored at 8 P. M. Counting from Old Head, at Kinsale, my last departure, 115 days passage, of which time lay at anchor in Straits of Sunda or Banca 48 hours. Distance sailed, O. H. K. to Java Head, 15,034, from Java Head to Hong Rong, 2521 miles. Had no accident of any kind to the ship. She sailed better than ever before, and is still as *strong* as ever. Of nine ships that sailed nearly with us, only one has arrived, an English *iron clipper;* and so the ship keeps up her good record."

Always carrying heavy dead weight cargoes, the *New Era* maintains her character for making good passages, without complaining in any way. From Hong Kong the ship went to San Francisco in 51 days, with 2292 tons general cargo. Writing from this port, reporting his arrival there March 7th, 1876, the Captain adds: "The ship stood the heavy weather bravely, *and is as tight as ever.* Three ships are here that sailed before me; all made long passages, had much heavy weather and received a good deal of damage.

Messrs. J. Henry Sears & Co., of Boston, having become managing owners of the *New Era*, the following letter is of interest here:

BOSTON, May 23d, 1876.

MESSRS. GILDDEN & WILLIAMS,

Dear Sir—In reply to your inquiry as to the present condition of the ship *New Era*, and how she has performed her work since she has been under our management, we have to say that she still maintains the high reputation which she deservedly held at the time when she came under our control. At that time, although we had seen the ship whilst she was building, and had confidence in her *strength*, yet with the knowledge of her having put into Mauritius on her passage from Calcutta to Boston, we, before buying into her, looked carefully into the causes that led to it, and were well satisfied that it was occasioned by unavoidable circumstances, and not in any way by weakness of the ship.

She has since performed very hard work, carrying heavy cargoes of wheat and coal, and does not show the least sign of strain or weakness of any kind, and we have no hesitation in saying that we rank her among *the strongest and ablest ships that we own.* She has always obtained the highest rates of freight given to wooden vessels, even in such ports as Hong Kong, San Francisco and Calcutta, where it is well known ships are subjected to the most strict surveys and inspection.

The ship has the highest rating and class from our local Inspectors, and others who witnessed her construction, and our Underwriters have always, and do to this day insure her at the very lowest rates, and will take as large an amount at risk upon her as upon the very best ships.

We hand you with this sundry documents relating to the character of the ship, viz., letters (extract) from Whitney Bros. & Co., Calcutta, to their house in this city; certificates of Boston Uuderwriters; certificates of the Port Wardens of San Francisco relating to the last cargo carried by the ship; and the letters of Captain Sawyer addressed to us from the various ports the ship has been in, that you may see all that he has said about her, in accordance with our instructions to inform us always upon arrival of the condition and performonce of the ship. These papers confirm our own carefully formed opinion, *that the New Era was thoroughly well built, and that she will always do her work as ably and wear as well as other ships that are constructed upon the more familiar principles of ship building.*

J. HENRY SEARS & CO.

(Notarial copy.)

PORT WARDEN'S CERTIFICATE.

State of California, } Office of the Board of Port Wardens.
Port of San Francisco. }

March 8th, 1876.

The undersigned, one of the wardens of the Port of San Francisco, duly commissioned and sworn in accordance with the act authorizing the appointment of Wardens for the Port of San Francisco, hereby certify that by the request of Messrs. Macondray & Co., I surveyed the hatches of the American ship *New Era*, Sawyer, Master, from Hong Kong, with general cargo, and found her well tarpaulined and properly secured.

Cargo in sight dry and in good order. Surveyed from day to day during the discharge of her cargo, which was completed March 27th, 1876, and found it well stowed and dunnaged, and it was all landed upon the pier in superb condition, excepting a few packages of sundry marked lots of merchandize, which constituted her great cargo, that were slightly stained by salt water and sweatage arising therefrom. The damage to cargo was so slight that I deem it worthy of more than passing notice, and hereby further certify that said cargo was landed upon the pier in better condition than any like cargoes landed from any vessels, including many first-class *iron* ships that landed their cargoes under my supervision. All which proves that said ship, constructed as she is, on late improved scientific principles as an experiment in ship-building, was remarkably well built, *and is of more than ordinary strength,* consequently competent to perform any required voyage for the transportation of cargo.

ISAAC SWAIN, *Port Warden.*

The "CERTIFICATE OF CLASSIFICATION" issued by the "American Lloyds Universal Record of Shipping" shows that the *New Era* has been rated A 1*, 12 years; and the original survey pronounced her *a model vessel in type of construction*—George Frazer, Surveyor, Boston.

The "CERTIFICATE OF CLASSIFICATION" of the "American Lloyds" vouches that "the requirements governing the construction of an A 1, 12-year ship have been fully carried out and exceeded in building and fitting this ship for sea—of an easy medium model, *combining great strength with good sea-going qualities,*" and rates her 9 years A 1*, with a right to continuation of Character,—John Devereaux, Surveyor, Boston, May 23d, 1870.

LETTER OF J. HENRY SEARS.

BOSTON, June 7, 1876.

Messrs. GLIDDEN & WILLIAMS:

Gentlemen—While in San Francisco a few weeks since, I chartered the ship *New Era* to load wheat (1553 tons) for Europe, procuring for her the highest freight then being paid for any ship. The *New Era* had previously carried wheat from San Francisco, delivering the cargo in fine condition, and the same parties were anxious to load the ship again, and I think many would have given her the preference over any ship then in that port. Examined the ship and found her to be in excellent order and condition, showing no signs of weakness; and Captain Sawyer said to me, SHE HAD ALWAYS BEEN TIGHT, *and always delivered her cargo in good order.* Since she was last caulked she had carried three heavy cargoes, long voyages, and although she had been lying in the port of San Franscisco *two months*, the Surveyor reported the ship did not require caulking before loading, as most of the ships lying in that port do.

From my own examination, and the reputation the ship has in San Francisco, *I believe her to be as strong, and that she will command as high a rate of freight as any ship afloat.*

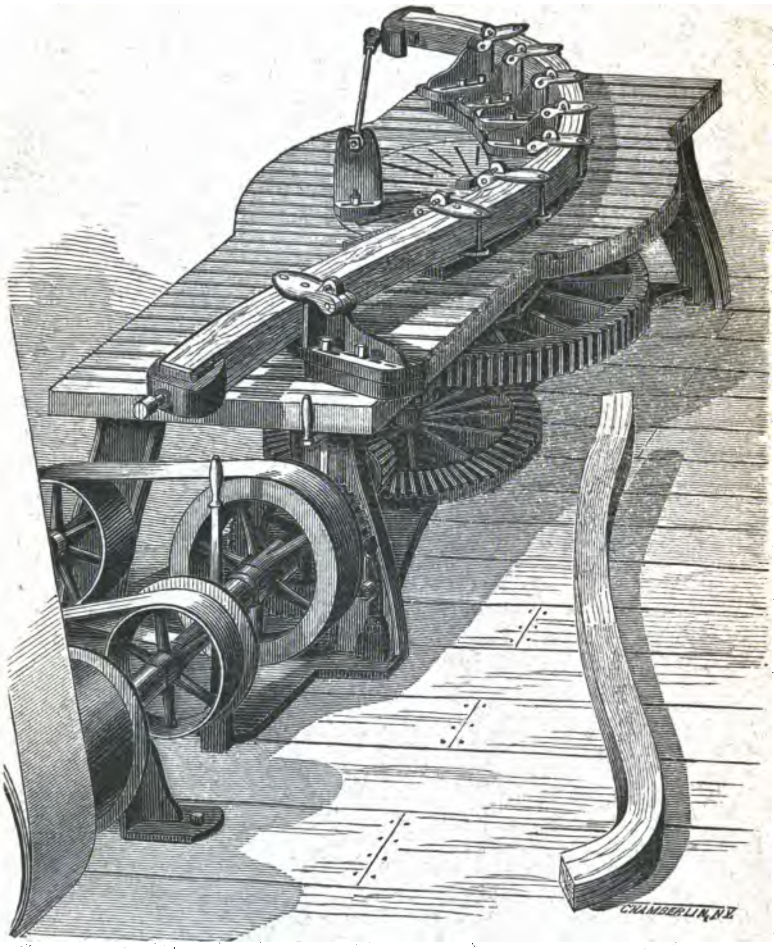
J. HENRY SEARS,
Firm of J. Henry Sears & Co.

A PRIZE MEDAL AWARDED.

When the International Exhibition at Philadelphia opened, it was determined by the owners of the *New Era* to offer her as a competitor for an award against any sailing ship in the world. For this purpose her model, calculations, specifications, surveys, and record of performances were placed on exhibition. In a letter to the judges, Messrs. J. Henry Sears & Co. say: "We think that ships actually built, whose performance is a matter of record, rather than speculative models and plans of vessels not built, should be proper subjects to come before the Board of Judges; their merits to be determined upon a tangible rather than a speculative basis."

The judges of the group having jurisdiction of naval subjects were gentlemen representing Great Britain, Brazil, and the United States. They unanimously recommended an "*Award for strength and superior sea-going qualities, with capacity and moderate draught.*" The Centennial Commissioners have confirmed their judgment and granted a medal, and here we rest in presenting the history of the first bent timber ship—the well-named NEW ERA.

No. 6 BENDING MACHINE,


CHAMBERLIN, N.Y.

For building Vessels of 250 Tons and under.

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